

# **FY 1999-2000 Basic Research Program**

## **Research and Advanced Concepts Office**

**June 1999**



**United States Army Research Institute  
for the Behavioral and Social Sciences**

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# **ARMY RESEARCH INSTITUTE**

## **Basic Research Program FY 1999-2000**



**Research and Advanced Concepts Office  
(RACO)**

**6/1/99**

## FOREWORD

If the joy of science is discovery, it is the business of science to communicate these findings. This document concerns the business of science. The purpose is to describe the individual efforts comprising the basic research program of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). However, we hope we have still communicated some of the joy.

ARI's mission is to maximize individual and unit performance and readiness to meet the full range of worldwide Army missions through the social sciences. Advances in theory, knowledge, and methodologies are critical to accomplishing this mission. This is the function of ARI's basic research program. This program is directed by the Research and Advanced Concepts Office (RACO) of ARI.

RACO is the locus of an ongoing collaboration between the world of behavioral science and the military community. This collaboration sets the stage scientifically for new behavioral technology and makes available the fruits of fundamental research to behavioral technologists in soldier-oriented R&D. The integral position within the ARI structure of RACO and of basic research within the ARI program facilitates the application process by the transfer promising findings to the applied research units within ARI. It is the business of science that provides the purpose of these reports, however, success is measured by the utilization of this knowledge

The staff of RACO is always available for questions and discussion of our programs. For research reports or more information about RACO's programming, send requests to point of contact, Dr. Michael Drillings at [drillings@ari.army.mil](mailto:drillings@ari.army.mil) or call 703-617-8641.



Edgar M. Johnson, Ph.D.  
Director, Army Research Institute

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## INTRODUCTION

The mission of the Research and Advanced Concepts Office (RACO) is to develop the behavioral science base for future applied research aimed at improving the effectiveness of soldiers and Army systems. RACO is a way-station between the world of behavioral science and the military community. Searching out and advancing the state-of-the-art methods, theories and findings in behavioral science, encouraging projects most likely to contribute generalizable scientific principles and new knowledge, and supporting those efforts that have potential military relevance and likelihood of leading to behavioral technology are RACO's key research goals.

In RACO's contract programs, a Broad Agency Announcement (BAA) is issued each year to solicit both explanatory proposals (concept papers) and formal proposals relating to the announced program areas. In a given year, the BAA highlights the research objectives of special interest, and provides an open call for proposals.

There are four current RACO program objectives in addition to the continuing search for new insights and scientific breakthroughs. The current objectives are to:

1. Provide fundamental knowledge to improve the training of procedural tasks,
2. Provide fundamental knowledge to guide the development and assessment of small team leaders,
3. As the Army evolves from a Cold War force to the 21<sup>st</sup> century, understand and anticipate the impact of societal trends and changes in the Army and its mission on soldiers,
4. Provide an understanding of individual characteristics that can serve as the basis for improving the match between soldiers and their jobs.

The reader will find in these pages summaries of current, on-going RACO contracts and in-house projects for 1999 as well as recently completed projects from 1997&1998. This document provides a listing and brief synopsis of ongoing and recently completed research efforts. Project listings are organized into four distinct sections with specific title headings. These headings, described above, reflect RACO's program objectives, and each objective serves as the title for a particular section.

This program, however, is but one of many programs for which RACO has responsibility. Other programs in RACO are:

- Small Business Innovation Research Program,
- Small Business Technology Transfer Program,
- International Behavioral Science and Technology Watch,
- Graduate student apprenticeship program - Consortium Research Fellows Program – with the Consortium of Metropolitan Washington Universities,
- Outreach efforts to Historically Black Colleges and Universities,



- ACTII Program with Army Battle Labs, and
- Research support in behavioral and social science for the U.S. Military Academy.

Additional information about reports from the research efforts summarized in this document are available upon request from the author.

We wish to acknowledge the efforts of Consortium Research Fellows Jason Luoma and Tony Papa, and Dr. Jonathan Kaplan, in preparing this report.

## **RACO RESEARCH OBJECTIVE #1:**

***Provide fundamental knowledge and improved theories  
to support the training of procedural tasks.***

Research in this section provides information regarding the development of methods of training that provide improved comprehension of training materials and better long-term retention and generalization of skills.

## ***Ongoing Research***

## The Preservation and Decay of Military Skills

Contract #: N68171-95-C-9144  
Institution: Ben-Gurion University of the  
Negev, Israel Defense Forces

Contract Dates: 9/95-9/99  
PIs: Avishai Henik, Esther Brainin &  
Varda Ze'evi

### SCIENTIFIC OBJECTIVES

One known fact is that people forget what they have learned. Forgetting depends on a variety of factors such as the quality of the skills required (e.g., types of knowledge), subjects' characteristics (e.g., age and expertise), etc. Much of the published literature on memory is based on laboratory research and short-term studies. The present research is a long-term field experiment that examines memory at the end of soldiers' mandatory military service and at various points in time (6, 12, and 18 month) since release from the service when the participants are on reserve duties. In particular, we study military shooting skills of tank gunners and missile operators (i.e., Dragon and Tow). This study investigates:

- 1) the rate of skill decay;
- 2) the impact of skill refreshment on the rate of skill decay;
- 3) the relationship between individual characteristics, such as memory or KABA (the IDF equivalent of the AFQT), and
- 4) forgetting of military skills; and
- 5) the relationship between declarative and procedural knowledge of the tested skills.

### APPROACH

The study focuses on aiming and shooting skills of three weapons: Tow missiles, Dragon missiles, and tank main-guns. Soldiers are tested about three months before being discharged from the army and at various points in time after their mandatory service. Shooting performance is tested with weapon simulators.

The chronological aspect of the study is delineated in the table below. The plus sign (+) indicates testing. The three weapon systems are tested according to the time table below.

Testing period	Discharge	6 Months	12 Months	18 Months
Group A	+	+		+
Group B	+		+	+
Group C	+			+

For all groups, the difference in performance between the time of discharge and the first test constitutes an indication of change over time. In addition, the comparison of these performance differences across the three groups permits an assessment of change in performance as a function of elapsed time. The comparison of groups A and B with group C examines whether utilization of a simulator restores relevant knowledge, and to what

extent. The comparison of groups A and B examines whether the timing of refreshing of the skill using simulator (after 6 or after 12 months) affects performance.

Both practical (e.g., hit rate) and knowledge aspects of performance are measured at every testing point. In addition, various aspects of memory are tested at discharge. Memory tests include: verbal and visual free recall, paired associates, semantic memory, and memory for order.

### PROGRESS

We tested a total of 260 subjects at discharge. The numbers of subjects that were tested at later points in time (e.g., 12 or 18 months) were smaller: between 7 and 21 subjects per group (A, B, or C) and weapon. Several subjects who were tested in the first or second round of tests, were not available for testing after 18 months. We have not excluded them from the project yet, and hope to be able to test them in the future. This might enable us to look at performance after longer periods of time.

The current results show a decline in hit rate for tank gunners. This decline is relatively large after 6 months since discharge. Accuracy in shooting also declines both for horizontal and vertical deviations from target locations. For the two missile systems there seems to be only minor changes. The results for the knowledge tests are similar to the practical tests. The various memory tests are moderately correlated. Hence, it is quite possible that the various tests capture somewhat different aspects of memory.

### CONTRIBUTIONS TO BASIC SCIENCE

This project will add to our knowledge of changes in memory for skilled performance over extended periods of time. Moreover, it will supply information regarding possible predictors of such changes. This will help us understand the possible mechanisms involved in the decline (or forgetting), with time, of skilled performance. In addition, we look at the possible relationships between individual memory characteristics and other individual abilities and changes in performance over time.

### POTENTIAL APPLICATIONS

During the Gulf War, Wisher, Sabol and Kern (1991) conducted a study of individuals' readiness to serve. The findings of this investigation pointed to a significant reduction of military skills with elapsed time since the last period of training. Under certain situations there is a need to deploy armed forces on short notice, and possibly, with limited time and opportunity to practice military skills. Hence, it is important to develop efficient procedures for practice which include time parameters (e.g., how frequently should the tank gunner practice and for how long). These procedures and time parameters depend, among other things, upon the foreseeable decay of the given skill.

In this project we study the decay and preservation of military skills, in particular, the skills of missile launcher operators and of tank main-gun operators. We examine the rate at which these skills are lost and possible determinants of the rate of decay. Such research is valuable in enabling armed forces to cope with the problem and to demarcate policies for teaching and practicing military skills.

# Optimizing the Durability and Generalizability of Knowledge and Skills

Contract #: DASW01-96-K-0010  
Institution: University of Colorado

Contract Dates: 8/2/96 – 8/1/99  
PIs: Alice F. Healy & Lyle E. Bourne, Jr.

## SCIENTIFIC OBJECTIVES

The main focus of this research is on enhancing the generalizability, or transferability, of what is learned and retained in a variety of naturalistic and laboratory tasks. This new direction is prompted by two main outcomes of earlier studies. First, we found that durability of knowledge and skills in certain domains can be facilitated by “procedural reinstatement” procedures very similar to contextual priming procedures. Second, we found that typically the more durable the memory for a certain kind of knowledge or skill, the less generalizable it is beyond the circumstances in which training took place. Thus, we discovered training conditions that promote durable memory but constrain generalizability. In our current work, we are trying to discover ways of promoting the generalizability of those durable memories without sacrificing their durability.

## APPROACH

The specific issues that we are addressing include: (1) types of strategies and strategy transitions exhibited by learners in category learning tasks, (2) the relationship between the learning of examples and the learning of rules in conceptual tasks, (3) variations in contextual interference as a means to promote durability and generalizability of knowledge and skills, (4) the underlying causes of durability and specificity in digital data entry, (5) factors underlying the transfer and retention of spatial and motoric knowledge and skills, and (6) the use and durability of both general and specific knowledge in quantitative estimation.

## PROGRESS

The following are our findings concerning the above issues, their implications for training, and our current and planned follow-up investigations:

Types of strategies and strategy transitions exhibited by learners in category learning tasks. We found that monotonic changes in overall measures of performance during practice masked the complexity of changes in the learner’s basis of response or strategies employed. The implications for training are that instructors should monitor not only overall measures of performance but also the strategy employed by the trainee. When the most effective strategies are known, instructors would be advised to adopt procedures that can effectively bring these strategies forward earlier than usual in the training process. In our planned follow-up research, we seek to determine the role of prior knowledge in strategy selection.

The relationship between the learning of examples and the learning of rules in conceptual tasks. We found strong support for the rote-and-analogy paradigm, as opposed to the

rule-and-category paradigm, because we found that individuals' knowledge of the *thuh/thee* distinction, unlike their knowledge of the *a/an* distinction, does not conform exactly to the simple, general abstract rule included in the dictionary, but is rather more complex and involves information at various levels of abstraction. The implication for training is that individuals do learn complex rules involving different levels of abstraction when given sufficient specific examples but that they also benefit from explicit visual cues, reinforcement, and instruction concerning abstract, general rules. In our future research, we plan to examine the learning of novel linguistic rules so that we can develop general principles concerning the factors influencing the generalizability of known categories to new ones.

Variations in contextual interference as a means to promote durability and generalizability of knowledge and skills. Previous research has shown that in certain situations conditions that make initial learning more difficult improve the durability of memory and transfer of learning to new situations. Our findings were in accordance with predictions based on Battig's contextual interference principle. They imply that blocking material by category, which is frequently done in training, may aid initial acquisition but may not yield optimal retention. If durable retention is the goal, contextual interference during training is advisable. We also found that increasing task difficulty during study aided transfer to a new task as well as long-term retention of the original task. The implication for training is that enhancing the difficulty of training exercises will lead to improved retention and transfer. In our future research, we plan to explore this phenomenon further by examining different methods for enhancing task difficulty during training.

The underlying causes of durability and specificity in digital data entry. We found that the depth of processing forced by the particular format is an important factor determining durability and specificity. When durable and generalizable learning is the goal, use of a training format that forces deep semantic or cognitive processing is advisable. In our planned research, we will investigate the extent to which fatigue affects performance in this task, and we will explore methods for overcoming or counteracting the effects of fatigue.

Factors underlying the transfer and retention of spatial and motoric knowledge and skills. We found strong evidence that subjects' immediate memory for a set of navigation instructions is greatly affected by their mental representation of the space to which the instructions refer. More specifically, we found that memory varied as a function of the number of dimensions that the subjects were required to represent mentally in the task. The implication for training is that additional practice should be given whenever the task to be learned requires a three-dimensional mental representation, rather than simply a two-dimensional representation. Our results imply further that three-dimensional displays, such as those found in virtual reality environments, are not sufficient to eliminate the need for this additional practice. In our current research, we are examining in greater detail differences in performance when individuals work with three-dimensional as opposed to two-dimensional displays and form three-dimensional as

opposed to two-dimensional mental representations. In our future research, we plan to investigate the retention and transfer of the skill of comprehending navigation directions because of its general importance in aviation as well as in many other military tasks.

The use and durability of both general and specific knowledge in quantitative estimation.

We found that providing a small set of seeding facts or training with a very small amount of general information both led to large improvements in subjects' quantitative estimation skills. The implications for training is that seeding should be used wherever possible when quantitative estimation is required. In our future experiments, we plan to assess retention of quantitative estimation skills by exploring further the durability of improvements due to seeding. We also intend to examine the effects of seeding in other nonquantitative skills.

### CONTRIBUTIONS TO BASIC SCIENCE

The many research directions we have described here address a diverse set of issues. Nonetheless, they share the common theoretical goal of understanding the psychological principles underlying the acquisition, retention, and most importantly transfer of knowledge and skills. For example, we have proposed a procedural reinstatement principle according to which durable but specific retention results when the procedures, or operations, employed during acquisition are reinstated, or duplicated, at the time of the retention test. This principle has been shown to hold over a wide variety of task domains. We are presently searching for parallel principles that govern transfer and the generalizability of knowledge and skills.

### POTENTIAL APPLICATIONS

Our research is aimed at developing methods for optimizing the durability and generalizability of knowledge and skills. The need for such methods is particularly crucial to military tasks because there is often a long delay between training and encountering applications in the field. In addition, training circumstances can rarely capture the full set of circumstances under which these tasks are encountered in the field. The Army has come to rely increasingly on the use of distributed interactive simulation and virtual reality as training mechanisms. Although these novel procedures seem likely to be effective, it is not yet clear how durable and generalizable the knowledge and skills acquired under these procedures will be beyond the training environment.



## SOAR Emotional Synthetic Forces

Contract #: DASW01-98-K-0008  
Institution: USC/ISI

Contract Dates: 9/1/98- 8/31/01  
PI: Randall W. Hill, Jr.

### SCIENTIFIC OBJECTIVES

1. Contribute to the understanding of the functional role of emotion in battlefield decision-making.
2. Investigate the use of emotion in creating believable Command and Control (C<sup>2</sup>) agents for Joint Synthetic Battlespaces (JSB).
3. Investigate the role of emotion in guiding an artificial intelligence planning system to more effective and flexible planning.

### APPROACH

This effort builds on a C<sup>2</sup> planner we developed to model Battalion and Company level operations in a Joint Synthetic Battlespace (JSB). The C<sup>2</sup> planner generates, executes and repairs plans that are carried out by SOAR-based synthetic force agents. To model the role of emotion in decision-making, we will extend the C<sup>2</sup> planner by incorporating a theory of emotional appraisal into the decision process.

The rationale for this approach builds on the functional arguments for emotion made by Oatley (1992): (1) human action involves multiple, competing goals; (2) actions are taken in the context of limited resources and imperfect information; and, (3) much of human action is undertaken jointly with others. Consequently, emotions evolved to manage this process by organizing transitions and establishing priorities. To apply emotion in this way involves understanding the emotional signature of an event (i.e., should the event evoke joy, fear, etc.), Ortony, Clore and Collins (1988) developed a model of emotional appraisal that is used to gain an understanding of the emotional signature. Clark Elliott developed a computational realization of this model on which we base our implementation.

Our approach will implement a model of how emotional appraisal affects goal prioritization and action selection in the C<sup>2</sup> planner. The effects of appraisal and planning will be evaluated in the context of Army Aviation C<sup>2</sup> operations.

### PROGRESS

We have completed the initial prototype of appraisal that is described in a technical article by Jonathan Gratch referenced below. The prototype extends Elliott's model to encompass the deliberate reasoning capabilities required in command and control reasoning. Current work is focusing on how to use these appraisals to alter planning behavior.

### CONTRIBUTIONS TO BASIC SCIENCE

1. Jonathan Gratch wrote a technical paper entitled, "Why You Should Buy an Emotional Planner," that has been submitted to the International Joint Conference on Artificial Intelligence (1999).

2. We will develop a general theory of emotional appraisal. Whereas previous models only cover reactive behavior, our theory will address the role of emotional appraisal in deliberate decision-making.

#### POTENTIAL APPLICATIONS

1. Command and Control (C<sup>2</sup>) planning agents for Joint Synthetic Battlespaces. It should be possible to model the decision-making of C<sup>2</sup> staffs under various conditions that evoke emotional responses. This will add realism and variation to virtual and simulation training environments.
2. Games. There is a close relationship between games and simulation-based training. There are numerous possibilities for developing realistic agents for games based on this technology.
3. Believable agents. In applications such as virtual training environments, emotion can make an intelligent tutor or virtual teammate appear more believable, thus adding realism to the experience.

#### REFERENCES

- Oatley, K., (1992). *Best Laid Schemes: The Psychology of Emotions*. Cambridge University Press.
- Ortony, A., Clore, G.L., and Collins, A., (1988). *The Cognitive Structure of Emotions*. Cambridge University Press.

# **Using Virtual Reality to Improve the Learning, Retention, and Application of Spatial Mental Models**

Contract #: DASW01-96-K-0004  
Institution: The Catholic University of  
America

Contract Dates: 7/1/96 - 6/30/99  
PI(s): Marc M. Sebrechts & Deborah M.  
Clawson

## **SCIENTIFIC OBJECTIVES**

Spatial mental models play a critical role in a wide variety of activities ranging from finding one's way through a city to developing a strategy for planning a hostage-rescue. Understanding the nature of these mental models and the power of virtual reality (VR) technology to augment our spatial skills is the central theoretical concern of this research.

Within this broad framework we are interested in understanding how learning through VR affects spatial mental models and how those models influence the ability to retain and transfer information to the physical space.

## **APPROACH**

We are following a two-pronged strategy in using virtual environments as a testbed for assessing spatial skill. One approach focuses on developing medium-fidelity models of physical space and assessing the effectiveness of such models for training and transfer to the physical space. A second approach explores alternative ways of using VR which differ from properties in the real world. These include variation in user control of movement as well as changes in the transparency of the space.

In each of a series of studies we are collecting a variety of measures on learning, retention, and individual differences. The learning measure consists of determining the length of time or the number of walkthroughs it takes someone to learn an architectural space. Retention is measured in several ways. In some cases, response times for relative location judgements are used as an indicator of the mental distance separating the objects. In other cases, ability to follow a route or identify locations of objects obscured from sight is measured. In addition, a drawing task is used in which participants are asked to draw a two-dimensional overview of the building. Finally, we measure several characteristics of the individuals that may relate to performance on our spatial tasks, including visual memory, mental rotation, field dependence, spatial scanning, and associative memory.

## **PROGRESS**

Three virtual environments have been developed for experimental study. The first is an evolution of a previously modeled two-story community center. The other two are textured models of the School of Architecture and Planning and the School of Music on our campus.

Six experiments explored training to navigate using these architectural spaces. Two experiments demonstrated that when participants were given full control of rotational

and forward movement in VR, training was nearly optimal. However, partial control resulted in worse training than having no control. In all cases, training in VR using walkthroughs led to spatial mental models that reflected route distance in the building. Differences in visual memory were related to variations in rate of learning as well as accuracy of the resultant spatial mental model.

Two experiments assessed the effect of modifying the VR training to allow viewing of the entire space using transparent walls. VR training in the transparent-walled building led to substantially more accurate floor-plan drawings than VR training in the traditional opaque-walled building. This advantage was mainly due to a surprisingly advanced understanding of the architectural aspects of the building's layout (e.g., connection of rooms and alignment of floors).

Two other experiments demonstrated that VR training was similar to real-world training, and was quicker and transferred better to navigating the real-world building than floor-plan training. However, this held only when the testing route was traveled in the trained direction. Individual differences in spatial scanning affected the success of transfer from VR to a comparable physical space.

### CONTRIBUTIONS TO BASIC SCIENCE

Mental models developed from VR training reflect properties of the simulated environment. Learning a route in an opaque building leads to a mental model that maintains route distance among remembered objects, whereas learning a route in a transparent building leads to a mental model with both route and Euclidean distances. In addition, the method of assessment reveals different aspects of the spatial mental model. A same-different task results in shorter response times for greater distances, reflecting a typical semantic distance effect. An orientation task results in longer times for greater distance, reflecting a physical distance effect. In addition, transparency enabled participants to quickly acquire survey knowledge about a structure that typically requires substantial time in the physical world. Finally, despite multiple views in some of our VR training conditions, test performance depended on the relationship between route orientation during training and testing. This extends the types of spatial layout in which orientation specificity of mental representations has been demonstrated.

### POTENTIAL APPLICATIONS

The results suggest that several alternative VR techniques may be viable in providing assistance for mission rehearsal, reconnaissance, and general navigation. Relatively simple spatial layouts can be learned quickly and effectively with this approach. In addition, training using transparent environments can lead to the acquisition of survey knowledge in a fraction of the time typically reported for real-world training. This may be especially important in other contexts, such as the development of situation awareness. It may also be important to attend to issues of spatial ability in assignment of individuals to a task, especially as those tasks become more spatially demanding. It is intriguing that our initial results suggest that the more elaborate visual tools, such as VR, may actually reduce the importance of individual differences for certain tasks.

## **Enhanced Learning and Retention of Land Navigation and Target Recognition Skills Through Equivalence Class Training**

Contract #: DASW01-96-K-0009  
Institution: Queens College/CUNY

Contract Dates: 6/24/97-7/7/99  
PI: Lanny Fields

### **SCIENTIFIC OBJECTIVES**

The scientific objectives of this research are to: (a) identify the pretraining variables that maximize the learning of new equivalence classes while minimizing the instructional resources required for training, (b) study how class membership transfers from equivalence classes to new stimuli that are perceptually similar to class members, (C) study how actions trained to occur to one class member transfer to all class members and to stimuli that are perceptually similar to class members (i.e., transfer to training), (d) identify methods and procedures that can be used to establish perceptual classes and control their extent, and (e) study the integrity of equivalence classes and their response evoking capacity over time (i.e., retention).

An equivalence class is a set of stimuli that function interchangeably even though the stimuli are perceptually disparate and do not resemble each other. An example is a topographical map representation of a terrain feature, the feature as viewed from a given elevation, its name written in English, and its name as spoken in Farsi. Another is the visual representation of a given aircraft, its infrared signature, its acoustic signature, its technical designations as written and heard, and its nickname as seen and heard. Equivalence class membership also extends to other stimuli that are perceptually similar to the class members. If so, the equivalence class and the perceptual variants of the class members constitute a generalized equivalence class. Finally, actions trained to occur to one class member will then transfer to all member of the equivalence class and to the stimuli that are perceptually similar. Thus, if a pilot learns to take a particular action with respect to the name of an airplane, and is then confronted with a novel infrared (IR) signature that resembles the IR signature that is a member of the equivalence class for a particular enemy airplane, the pilot will take the trained action. Such an action would be appropriate and adaptive. Conversely, the novel IR signature might be that of a friendly aircraft. In that case, taking action would lead to a tragic friendly fire accident. A detailed understanding of the processes involved in the formation of equivalence classes and their extension to novel instances can influence the appropriateness of the actions taken by military personnel when confronted with cues in a field setting that differ from those experienced in training.

### **APPROACH**

College students with cultural and educational backgrounds that match the diversity of military personnel were subjects in the experiments. During the second year of research, we expanded the type of stimuli used as members of equivalence classes to include materials that were of military relevance, while at the same time being somewhat abstract. Thus, we used images of terrain landmarks, along with their symbolic

representations which included topographical maps and orienteering symbols. In addition, satellite images of landmasses presented as banded elevation, shaded relief, false color, and gray scale were used. Finally, dimensional variations of these stimuli were included in the research to study transfer of responding to degraded variants of the above mentioned basal stimuli. Regardless of stimulus content, basal stimuli were represented by letters (A, B, C, etc), and dimensional variants of a stimulus were represented by a letter followed by a prime (e.g., C).

Matching to sample procedures were used to study equivalence class formation. For example, to establish a 4-member equivalence class represented by the letters A, B, C, and D, the stimulus relations AB, BC, and CD, would be trained for at least two classes, 1 and 2. To train AB, A1 would be presented as a sample with B1 and B2 as comparisons; selecting B1 would be reinforced. When A2 was presented as a sample, the selection of the B2 comparison would be reinforced. Training would continue to 100% accuracy. The BC and CD relations would be established in a similar manner. To demonstrate the emergence of equivalence classes, a subject must immediately identify the class-related comparisons in all remaining untrained stimulus pairs in a set (DA, DB, CA, AD, AC, BD, DC, CB, and BA) without benefit of feedback. Thus, on DA tests, D1 would be presented as a sample with A1 and A2 as comparisons. Selection of A1 given D1 and of A2 given D2 would indicate recognition of class membership of the D and A stimuli.

Determining membership of a variant with a basal class member was determined by presenting variants as samples with basal members as comparisons. Selection of a basal stimulus in the presence of a variant signifies that the a particular variant was a member of the same class as the selected comparison.

## PROGRESS

### Formation of Equivalence Classes

1. Equivalence classes were formed using tactual stimuli only. In addition, individuals immediately recognized the visual equivalences of the previously found tactual relations. This data demonstrates that visual or auditory cues are not needed form equivalence classes, that the formation of equivalence classes resulted in reliable cross modal transfer of sensory and relational information, and that the formation of equivalence classes is more general than had previously been expected. Tactual cueing, then, could be used for the communication of symbolic equivalence based information.
2. By using the simultaneous protocol, we determined how two parameters of equivalence classes influence likelihood of class formation and speed of learning new conditional relations.
3. The prior establishment of a generalizable transitivity repertoire or the prior measurement of primary generalization gradients both increased the likelihood of subsequent formation of equivalence classes.
4. The measurement of an individuals ability to spontaneously interrelate perceptually disparate stimuli appears to be highly predictive of the



subsequent formation of new equivalence classes. Assuming experimental replication, this finding suggests that similar tests could be used to identify candidates with similar abilities.

5. We demonstrated that likelihood of equivalence class formation is controlled by the number of different negative comparisons used when establishing the conditional relations that are the prerequisites to equivalence classes. This occurs in the absence of any reinforcement. We showed that the likelihood of forming equivalence classes is influenced by an inverse interaction between number of negative comparisons and reinforcement. These data suggest that feedback need not be used to induce the formation of equivalence classes.
6. We discovered, that forced choice generalization tests that prompted stimulus pairings alone with no reinforcement was an effective means that establish perceptual classes.
7. Perceptual classes were formed from dimensional variants of satellite images of specific landmasses. These data show that the breadth of class membership can be influenced by the context in which measures of class membership are obtained. These results suggest that that context in which perceptual classes are established must be precisely controlled to optimize performance in new settings.
8. A theoretical analysis of generalized equivalence classes was developed. This analysis, then, provides an explicit guide for research that addresses the establishment and measurement of generalized equivalence classes. It also shows that the classes studied thus far were incompletely developed, and incompletely documented.
9. For a particular test format, the range of variants that function as members of the generalized equivalence class is precisely predicted by the range of variants that function as members of the perceptual class, as measured prior to the formation of the equivalence classes. This information is a importance since it implies that the range of situations that should evoke particular behavior could be precisely determined in a instructional setting.

### CONTRIBUTIONS TO BASIC SCIENCE

The discovery of the variables that influenced likelihood of equivalence class formation provides a basis for the understanding the processes responsible for the development of a type of conceptual category that plays a pivotal role in language development and the governance of large domains of complex human behavior.

Large ranges of human behavior are also controlled by such classes. Our research has discovered some new variables that influence the formation and breadth of perceptual classes. These data are giving rise to a new theory that can account for the development and breadth of perceptual categories.

Wide ranges of human behavior are also influenced by equivalence classes. For these classes to exert control, however, the relations in such a class and the behaviors that are controlled by such class must transfer to other stimuli that are perceptually similar to each class members. Our research has provided a theoretical framework for studying this phenomenon, has identified some of variables that influence that process, and has

provided the basis for developing a theory that accounts for the processes involved with the formation and extension of equivalence classes.

### POTENTIAL APPLICATIONS

The development of land navigation involves the learning of a variety of skills. Some are the equivalences among topographical representations of a terrain feature, its visual representations in 2 and 3 dimensions and its name in English and some foreign language. It is also necessary to extrapolate from these features to variations seen in actual field settings. The identification of procedures that enhance the establishment of equivalence classes and their extension can be used to develop improved methods on teaching land navigation skills to military personnel. A similar argument can be made for teaching and transferring target recognition skills. The electronic battlefield of the future will involve the presentation of a vast amount of information about a given event. The information will be presented in a variety of forms many of which will not necessarily be perceptually similar. Recognizing the equivalence of these representations will be critical to effective functioning in such a setting. The information being gathered in our research points to methods and procedures that can enhance the acquisition of these equivalences, and enhance their transfer to new and appropriate settings. Thus, the research can enhance an individuals ability to to function effectively in any of these capacities.



## Human Self-Assessment in Training and Testing

Contract #: N68171-96-C-9049  
Institution: Stockholm University

Contract Dates: 11/96 - 06/99  
PI: Peter Hassmen

### SCIENTIFIC OBJECTIVES

The goal of this project is to better understand the interaction of retention and cognition and the possible contribution of gender differences in cognitive processing. Two experiments will address these issues. The first experiments' objective establishes how much of the learned material is retained as a function of self-assessment of level of learning obtained at end of the final learning trial after specified time intervals. The second experiment extends current knowledge of gender differences in multiple-choice testing to investigate whether an individual uses gender stereotypical schematic or aschematic processing as a possible predictor for the dissimilarities observed between and within test scores of men and women.

### APPROACH

In the first experiment, participants are assigned to one of two experimental groups, one group making self-assessments and one group not making self-assessments. The groups are balanced with respect to the number of males and females respectively. Learning and retention are measured by the number correct items on a multiple-choice test. The participants are tested for retention after one week, six weeks, or twelve weeks.

In the second experiment, an equal number of males and females are tested in the United States and in Sweden. In addition to answering the multiple-choice questions, each participant completes the Bem Sex Role Inventory as a measure of gender schematic/aschematic processing.

Data in both experiments is analyzed by means of analyses of (co)variance as well as multivariate analyses of variance. In the second experiment, inter-individual variation among the male participants is compared with that among the female participants.

### PROGRESS

Data collection has been completed, both for the retention study as well as the multiple-choice study. A revised manuscript has been resubmitted to the *Journal of Educational Psychology* (entitled "Performance on the Swedish scholastic aptitude test: Effects of self-assessment and gender"). Additional manuscripts are being completed and will be submitted during the spring.

### CONTRIBUTIONS TO BASIC SCIENCE

The first experiment provides valuable data toward theories which (a) relates retention of learned material after specified time intervals to self-assessment, and (b) relates the extent which differences may be attributed to gender-role.

## POTENTIAL APPLICATIONS

Widespread training applications exist. Training prepares the trainee for future situations when knowledge or skill acquired during the training is required. Forgetting equates to lost training dollars. Thus, retention is essential. Full human resource utilization requires full employment of talent regardless of gender. Any gain in retention represents a potential savings of millions of dollars in training costs. Our study focuses on understanding of gender differences in self-assessment of learning and schematic processing to help improve understanding of associated training issues to improve training efficiency and reduce training costs.

## **Using Latent Semantic Analysis and Construction-Integration Models to Assess Knowledge and Improve Instruction**

Contract #: DASW01-98-K0004  
Institution: University of Colorado

Contract Dates: - 6/30/01  
PIs: Thomas K. Landauer &  
Walter Kintsch

### **SCIENTIFIC OBJECTIVES**

This project has a dual focus. As an end-point for evaluating and informing our theories and methods for automatically understanding and generating verbal meaning, we will design and test a prototype for a tool that could be used for matching jobs and training in the Army with personnel best able to profit from the training and perform target tasks. The principal existing theory and method upon which we will rely is Latent Semantic Analysis (LSA). Latent semantic analysis provides a powerful method to capture the static, central meaning of words and their combinations in short utterances, such as expository paragraphs and employment records, after training on large bodies of representative text. However, in its current form LSA does not represent significant temporary modifications of meaning such as are found in word combinations with highly interactive, "non-linear" meanings, such metaphorical expressions and predications like "my lawyer is a shark" or "the hunter shot the deer" vs. "the deer shot the hunter." Thus, a second principal goal of the project is to improve our understanding of LSA, and extend its applicability to modeling the dynamics of verbal meaning expression, and to modeling wider domains of human cognition in general. The main additional mechanisms to be explored will be based on spreading activation (neural net) dynamics such as those underlying Construction-Integration theory.

### **APPROACH**

There are three main directions that this project is taking to address the issues outlines above. They are as follows: 1) Analyze instructional texts by LSA to determine interrelationships and overlap in instructional domains and develop methods for the automatic assignment of optimal instructional texts to learners with varying goals and background knowledge, 2) Extend LSA theory and simulation techniques for text comprehension, and finally, 3) Explore theory and method for statistical approaches to language generation.

### **PROGRESS**

In more detail, progress on the main sub-projects to be undertaken according to initial planning is outlined below.

Analyze instructional texts by LSA to determine interrelationships and overlap in instructional domains and develop methods for the automatic assignment of optimal instructional texts to learners with varying goals and background knowledge

The first issue is to find a suitable text database. The database has to be rich and varied enough to allow us to use LSA. We need a large number of written documents, in

electronic form, focused on some topic of interest in order to be able to construct a semantic space that is sufficiently informative for our purposes. Second, we want a topic that is of interest to the Army. It would be possible, of course, to develop our tools in domains distant from Army concerns. However, if we can specify a domain that is of direct interest to the Army and that at the same time is suitable for our purposes, this would hold obvious advantages. Therefore, we have initiated a systematic exploration of Army written documents. This has and will involve exploring and downloading databases from the Internet.

We have identified a promising set of documents in a database on "aviation logistics" containing field manuals and Soldier Training Publications. There are 1519 documents, each about one page long. This database is complex and varied and can serve as a good test bed for the development of our prototype system. A document-by-word matrix will be computed and subjected to LSA to obtain a semantic space of about 400 dimensions. This space will serve as the basis for much of our future work.

In addition, we are exploring opportunities to collaborate with past and proposed projects on Army leadership programs that may make extensive data on personnel backgrounds, test results, and performance measures available. One such program has been under the leadership of Robert Sternberg of Yale University. One goal of this work, or of a similar project carried out in some other real-world environment if this one does not work out, will be to develop, extend and evaluate the use of the LSA-based methods for analyzing free-text ("essay grading") as tools for assessing individual and group cognitive and operational decision-making competencies. For example, rather than relying on multiple choice testing to determine what procedures an officer would think of and choose to employ in a problem situation, the officer could be asked to describe planned actions in fairly extended spontaneous verbal discourse. LSA could then compare the conceptual/semantic content of the statement with those of experts or other officers who are more or less successful in dealing with the same or similar situations (again, the similarity possibly judged from written descriptions by LSA). As another part of such an endeavor, we would also try to use our developing methods of automatic text comprehension and generation to select or create practice and test scenarios for training programs and to analyze written responses. These "situated" problems will call for and realistically test improved capabilities of our modeling theories and methods.

#### Extend LSA theory and simulation techniques for text comprehension

Three pilot projects serve as background studies to investigate the ways in which LSA simulates human language processing, the ways in which it differs, and to guide the exploration of additional mechanisms and simulation techniques to accomplish greater coverage and precision. This kind of research is crucial for the success of the goals of the project; if we want to use LSA intelligently, we need both to understand how it works and its limitations, and to develop theory and techniques to extend its range.

1. In one study now in progress we investigate the role of syntax in comprehension. LSA does not use syntax, but people do, both in comprehension and production of text. LSA often describes very well what people do. How is this possible if it disregards something as ostensibly important for human language processing as

syntax? In this experiment, we ask how well people can understand sentences if they are not allowed to rely upon syntactic cues. We scramble the order of words in naturally occurring sentences and ask people how well they understand the semantic information conveyed by these sentence ("Tell me what happened?"). Initially we manipulate text type (narrative vs. expository) and sentence length (10 words vs. 20 words). Later we will extend the materials in length and complexity and add additional measures of human comprehension.

2. In a second project, a simulation of how human readers comprehend non-linear sentences has been constructed. Psycholinguists have accumulated a great deal of very informative and valuable information describing how humans understand such sentences. The question is: are our theories sufficiently powerful to explain the major known phenomena in this field? Specifically, does the combination of LSA with the comprehension model of Kintsch (1998) provide such an account? Initial progress on this question has been good. For a number of exemplary sentences that exhibit strong "non-linear" effects of word combinations, including metaphor, predication and semantic asymmetries, models that extend LSA by emphasizing shared meaning components (as represented in LSA semantic space) rather than simply adding components, have given convincing accounts of the dynamic meaning changes involved.

These preliminary, "manually-constructed" modeling results will guide a broader attempt to model the same processes with automatic computer-based simulation models based on the same principles. If successful—and we are fairly confident of a least a useful degree of success—incorporating these extensions into the analyses by which we match characterizations of people with characterizations of training materials and tasks will improve their accuracy and scope.

#### Explore theory and method for statistical approaches to language generation.

In a third project, we are exploring ways to generate meaningful language rather than to understand it. We want to start with LSA vector representations of a sentence or paragraph and generate an utterance with acceptable lexical content and syntax that has the same meaning. Initial plans call for using multiple constraint satisfaction methods to choose words and corpus-statistics bigram and trigram language model techniques, enhanced with LSA context-to-word similarities, to determine natural ordering. The extent to which such a process is sufficient to approximate normal human speech, and in what ways it is not, will constitute an important set of scientific problems. At the same time, any substantial degree of success will help in the development of simulation tools, most directly for generating practice and test scenarios, but also for basic understanding that can help us improve our systems for understanding of text.

### CONTRIBUTIONS TO BASIC SCIENCE

This project will improve our understanding of LSA, and extend its applicability to modeling the dynamics of verbal meaning expression, and to modeling wider domains of human cognition in general. This will be explored using spreading activation (neural

net) dynamics such as those underlying Construction-Integration theory, thus linking work in these two areas.

### POTENTIAL APPLICATIONS

This project has many potential applications that will be of high utility for the Army. First in terms of selection and training by facilitating the matching of people with training materials and tasks will improve their accuracy and scope based on specific characteristic of both the individual and training program. Evaluation of these theories and methods for automatically understanding and generating verbal meaning will involve designing and testing a prototype for a tool that could be used for matching jobs and training in the Army with personnel best able to profit from the training and perform target tasks.

Second, applications exist in terms of developing methods of automatic text comprehension and generation to select or create practice and test scenarios for training programs and to analyze written responses. This will help in the development of simulation tools, most directly for generating practice and test scenarios.

## **Uncertainty Monitoring and Information Comprehension**

Contract #: DASW01-98-K-0006  
Institution: Morris Brown College

Contract Dates: 8/1/98-7/31/99  
PI: David Washburn

### **SCIENTIFIC OBJECTIVES**

This project is comprised of three experiments designed

- (a) to identify individual and group differences in the ability to monitor one's own level of psychological uncertainty to assess its role in judgement and decision making;
- (b) to determine correlations between this metacognitive ability to monitor uncertainty and other mental abilities, individual or group characteristics, and physiological measures of interest to the Army;
- (c) to assess the influence of training, time-pressure, and fatigue on uncertainty monitoring ability; and
- (d) to increase our understanding of the interaction of uncertainty, metacognition, and decision making by producing a computational model of decision making that includes components both of uncertainty and monitoring, and by producing path analyses of uncertainty monitoring and correlated mental abilities so as to determine which cognitive skills and processes support or give rise to others.

### **APPROACH**

Volunteers will be tested on a battery of cognitive tasks to provide measures of attention skills, situation awareness, temperament, and other mental abilities. Additionally, a test of responsiveness to one's own uncertainty will be administered. This task uses psychophysical methods empirically to define each individual's region of uncertainty, and then to determine the degree to which each person monitors and responds adaptively to uncertainty. Relationships between this metacognitive ability and other mental or personality characteristics will be identified. Subsequently, various training procedures will be attempted to improve the adaptive response to uncertainty.

### **PROGRESS**

Since the project began in October, 1998, we have developed most of the software for the assessments to be used in this experiment. It is anticipated that testing of participants will begin no later than mid-March.

### **CONTRIBUTIONS TO BASIC SCIENCE**

These data will illuminate the basic nature of metacognitive abilities and their role in judgment and decision making. The lines between the cognitive constructs of attention, working memory, executive function, and intelligence are becoming increasingly blurred within the literature, suggesting that it is impossible adequately to investigate one component without also measuring many others. The present study promises to relate one particular aspect of executive function (uncertainty monitoring) to numerous better-understood constructs like attention and personality. These inter-

construct relationships may in turn account for the pronounced individual differences and group (e.g., children versus adults, adults versus elderly, normally developing versus ADHD) that are observed in metacognitive ability.

#### POTENTIAL APPLICATIONS

The data that will be produced here will have numerous Army-relevant benefits, including:

- (a) A better model of information comprehension and decision making will be produced for predicting behavior under conditions of uncertainty. The empirically-grounded assumption that drives this study is that different individuals make different decisions under comparable conditions of uncertainty, as a function of whether or not the individuals are monitoring their uncertainty and factoring this into the judgment.
- (b) Understanding the monitoring of uncertainty will guide the development of instrumentation and feedback to the soldier can be tailored to provide the right kind of guidance to each individual under each condition. Providing more information will be of little help for the soldier who is not monitoring her/his uncertainty (i.e., who is confident but wrong about a decision).
- (c) Selection for duties that are likely to involve uncertainty would benefit from a index of each soldier's sensitivity to uncertainty--an assay for which the distribution characteristics and psychometric properties have been identified.
- (d) In profiling mental abilities across constructs, a better understanding can also be achieved of the cognitive abilities that distinguish good leaders, communicators, teachers, sentries, and so forth from their less gifted peers.
- (e) Training procedures will be recommended that effectively and efficiently improve uncertainty monitoring and responsiveness.
- (f) The variables typically encountered by the soldier (fatigue, time-pressure) are likely to have quite different effects on performance and self-regulation of easy tasks versus those that create uncertainty. It is critical to identify these interactions so as to be able better to predict and prevent critical errors in judgment.



## **Learning To Suppress Competing Information: Do The Skills Transfer?**

Contract #: DASW01-98-K-2299  
Institution: University of Wisconsin-Madison

Contract Dates: 8/1/98 – 12/31/99  
PI: Morton Ann Gernsbacher

### **SCIENTIFIC OBJECTIVES**

The objective of this work is to continue to conduct laboratory research on the cognitive mechanism of suppression. Suppression is conceptualized as an active dampening of the automatic activation of mental representations. Thus, suppression attenuates the interference caused by the activation of inappropriate or irrelevant information.

During the previous funding period, I discovered that explicit training in assessing competing lexical, pictorial, and grammatical information improved subjects' ability to suppress such information. These training interventions were "domain specific," that is, subjects who were taught to assess the nature of competing lexical information (i.e., the inappropriate meanings of homonyms) improved their ability to suppress competing lexical information; subjects who were taught to assess the nature of competing pictorial information (i.e., the typical-but-absent members of scenic arrays) improved their ability to suppress competing pictorial information; and subjects who were taught to assess the nature of competing grammatical information (i.e., the incorrect parse of syntactic phrases) improved their ability to suppress competing grammatical information.

Does this explicit training transfer across domains? That is, does explicit training in assessing competing lexical information improve performance in suppressing competing pictorial or grammatical information? Does explicit training in assessing competing pictorial information improve performance in suppressing competing lexical or grammatical information? And does explicit training in assessing competing grammatical information improve performance in suppressing competing lexical or pictorial information?

### **APPROACH**

Half the subjects complete a training session prior to performing an experimental task. During the training session, subjects are presented with 40 training sentences. The subjects are told explicitly that some of the 40 sentences will end in a homonym (i.e., a word that has several unrelated meanings). The subjects are given several examples (e.g., He dug with the spade). During the training session, subjects will also be presented with a test word following each of the 40 training sentences. The subjects are told that some of the test words following each training sentence are related to a meaning of the sentence-final homonyms, but not the meaning of the homonyms that is appropriate, given the sentence context (e.g., ACE). For each of the 40 sentences encountered during the training phase, subjects are required to overtly classify test words that are related to the inappropriate meanings, for example, classify that ACE following the sentence, "He dug with the spade," is related to an inappropriate meaning of spade. The subjects will also be required to state why the test word is inappropriate (e.g., stating something such

as, "ACE refers to a playing card, but the type of spade suggested in the sentence is a garden tool"). Each of the 40 training sentences are presented four times during the training session.

Following the training session, all subjects perform the pictorial-suppression experimental task, which involves viewing an array of objects, and after viewing each array, verifying whether a test object was present. Trials which require suppression are those in which the test object is typically found in a scene that comprises the objects that were present in the array (e.g., a farmer, pitchfork, pig, barn, and chicken typically occur in a farm scene).

By comparing the performance of the subjects who undergo the training with the performance of subjects who do not undergo the training, we can assess the transferability of the training intervention on the subsequent experimental task.

### PROGRESS

Progress to date has been limited give the limited funds available. Nonetheless, one experiment has been completed with very encouraging results. The preliminary data from this experiment suggest that explicit training can transfer across domains. More specifically, preliminary data suggest that explicit training to suppress interfering lexical information can improve performance in suppressing interfering pictorial information. Thus, being trained to suppress the interference caused by thinking of an inappropriate meaning of a homonym (e.g., the playing card meaning of *spade* as it is used in the sentence *He dug with the spade*) appears to improve the ability to suppress the interference caused by thinking of a typical but absent member of a pictorial scene (e.g., thinking that a *tractor* might be present in a farm scene.) Given the potential implication of these data, we shall attempt to replicate them before moving on to our next research goal.

### CONTRIBUTIONS TO BASIC SCIENCE

At the theoretical level, if explicit training in suppression in one domain leads to improved suppression in another domain then support for the hypothesis of one general, cognitive mechanism of suppression will be garnered.

### POTENTIAL APPLICATIONS

Discovering that explicit training in suppression in one domain leads to improved suppression in another domain has great theoretical and practical implications. At the theoretical level, if explicit training in suppression in one domain leads to improved suppression in another domain then great support for the hypothesis of one general, cognitive mechanism of suppression will be garnered. At the practical level, discovering that explicit training in suppression in one domain leads to improved suppression in another domain will demonstrate that persons' ability to suppress information can be improved, even without specific training in the domain in which suppression is required. Given the powerful role that suppression plays in numerous comprehension (and other cognitive tasks), this finding would lead to substantial applications for improving performance in numerous domains.

## ***Recently Completed Research***

## Research On Expert Approaches To Analysis

Contract #: DASW01-96-C-0061

Contract Dates: 8/20/96 - 9/30/98

Institution: BBN Systems and Technologies

PIs: Allan Collins & William Ferguson

### SCIENTIFIC OBJECTIVES

The goal of this research was to systematically study how military planners and scientists from different disciplines conduct inquiries. Based on the analysis of these data, an elaborated theory of epistemic forms and games was developed which has the potential to form the basis for development of tools and training to support expert analyses. There are recurring patterns or forms that are found among expert analyses. Some of the different forms that these analyses take are cost-benefit analysis, stage models, system-dynamics models, trends, critical-incident analysis, and situation-action analysis. Learning to analyze complex situations or systems implies mastering how to carry out investigations of phenomena guided by one or more of these target structures. The target structures that guide analysis are called *epistemic forms*, and the set of rules and strategies that guide analysis, are called *epistemic games*. Research and practice elaborate these basic strategies by adding specialized constraints. By exploiting these constraints systematically, experts can more productively explore any domain of inquiry.

### APPROACH

The research plan was carried out in two stages. First, materials were gathered to support investigation of difficult problems. The materials were used to conduct protocol experiments with expert subjects: half expert military analysts and half scientists. Second, the protocols were systematically analyzed in terms of the theory of epistemic forms and games. The work produced a report to the Army on the implications of the research for development of a system to support analysis and decision making.

The first stage developed a small set of problems that cover a diverse set of topics. The military problems were based on scenarios developed at the Army War College, and three military experts (a former Lieutenant General and two former Colonels) worked on the problems for approximately two hours each. There were four scientific problems that four PhD scientists worked on with backgrounds in physics, biology, psychology and history for two to three hours. Relevant materials were available to the subjects, and they were tape recorded as they worked. Their instructions were to explain at all times what they were trying to do and why.

In the second stage, data was analyzed in terms of the preliminary theory. Previous work had identified a preliminary set of twenty epistemic games that are frequently used in science, and the epistemic forms associated with each game, and the set of constraints or rules that apply in playing each game. The protocol analysis attempted to determine what epistemic games were being played, what constraints were being applied in playing the game, and what forms were produced.

### RESULTS

The analysis identified six different kinds of elements that the experts used: *epistemic forms* (target structures for the analysis), *epistemic games* (analysis strategies), *domain*

*frameworks* (organizing structures for guiding an analysis), *key constructs* (key variables that enter into different types of models), *heuristics* (rules of thumb, such as to look for positive feedback loops or lag effects), and *prompts* (issues raised for consideration by the experts).

**Epistemic Forms.** Epistemic forms are the schematic structures that guided the experts in their analysis. There was a progression of forms in the protocols, where subjects nested one kind of analysis inside another kind of analysis. For example, they often used a structural-analysis form, such as a list or stage model, in order to make a decomposition of the problem. Then within each component, they used another analysis form, such as a trend analysis or a cause-and-effect analysis, to elaborate their analysis. As another example of how they nested their analyses, they would sometimes start working out causal chains, which they then would develop into multi-factor models. In one case the biologist extended his multi-factor model into a system-dynamics model. Thus the analyses they constructed involved complex nesting of different epistemic forms. There were ten epistemic forms identified in the protocols: cause-and-effect analysis, multi-factor models, cost-benefit analysis, comparative analysis, trend analysis, stage models, lists, spatial decomposition, finite state models, and system-dynamics models.

**Epistemic Games.** Previous work implied a coupling between epistemic forms and games, such that there was one game for every form. The protocols showed that while there are epistemic games associated with each form, some analysis strategies are not associated with specific epistemic forms. The multi-purpose analysis strategies identified in the protocols included: hypothesis formation and testing, looking for and explaining anomalies, identifying factors or key constructs, constructing causal chains, countering the weak links, and countering from strength.

**Domain Frameworks.** Both military experts and scientists used general frameworks that organized portions of their inquiry. These are labeled domain frameworks, because unlike epistemic forms and games they include domain-specific content. In fact they are instantiations of particular epistemic forms. For example, one military analyst used an instantiated stage model to guide his analysis in one scenario. There was abundant use of analogies in the protocols, functioning as domain frameworks. Four examples of domain frameworks were: a confrontation stage model used by military experts, the law of supply and demand used by scientists, a frontier metaphor used by the historian, and the principle of attacking when your opponent is diverted used by the military experts.

**Key Constructs.** All the subjects identified key constructs that they worked from in building causal chains, multi-factor models, and in one case a system-dynamics model. These are concepts like the Munich pact in history or money supply in economics. They function as the building blocks in any type of theory the subjects develop. Four examples of key constructs different subjects used were: an Islamic war hypothesized by one military expert; labor supply and other variables from the supply and demand framework; negotiations, military preparation, and attack which were the three phases in the confrontation stage model; and the greenhouse effect used by scientists in a climate prediction problem.

Heuristics. Often subjects talked about processes and effects that were part of their toolkit for understanding the phenomena that they were dealing with, but that were less elaborated than the domain frameworks and more content specific than the epistemic forms. These heuristics included lag effects, time course, feedback loops, likelihood of effects, size of effects, positive vs. negative consequences, and side effects.

Prompts. There was a strategy that arose in the military protocols, that depended on the interaction between experts. The prompts occurred when one of the experts would bring up an issue for the group to consider. Any tool to support expert analysis would naturally have a set of prompts that it might use to provoke the experts to consider different alternatives. Examples of the prompts that occurred in the military protocols included consideration of negative consequences, potential actions, the legality of potential actions, the countries affected, and possible deceptions.

The protocols led to a proposed design of a tool to support expert analysis. Clearly the kinds of prompts that occurred would be very useful, and each epistemic form suggests a number of prompts that could be posed to experts. It was also apparent that there were a number of different types of costs and benefits that the experts considered (e.g., financial, effects of relations with other countries) and these could act as prompts in doing a cost-benefit analysis in considering different courses of action. The protocols also provided a rich source of domain frameworks and key constructs that can be built into such a tool.

### CONTRIBUTIONS TO BASIC SCIENCE

The research has implications for artificial intelligence, psychology, and education. With respect to artificial intelligence, the theory can potentially support a variety of expert advisory systems. For example, the theory could give advice to analysts on possible moves and constraints in analyzing their data. With respect to psychology, the proposed research provides a new approach to studying the inquiry process. With respect to education and training, future analysts and researchers can learn some of the most important epistemic forms and games to guide their analyses from the research.

### POTENTIAL APPLICATIONS

The most likely applications of the work to military problems are in developing computer-based tools or training to support analysis and decision making. An example of such a tool is STELLA, which is a computer-based tool for constructing system-dynamics models, a particular type of epistemic form. Depending on their construction, there are a large number of possible tools that could be constructed to support analysis and model building for different epistemic forms. The work identified the kinds of epistemic forms military analysts use, and how they are deployed in analyzing military scenarios. The work showed how this analysis could be used to design a tool that could support analysts in using different epistemic forms. Similarly, the possibility exists to develop specific training procedures to teach military personnel how to analyze situations more effectively, based on the analysis.

## **Informational Approach to Skill Transfer**

Contract #: MDA903-93-K-0006  
Institution: University of Illinois

Contract Dates: 8/21/93-8/20/97  
PI: Gavan Lintern

### **SCIENTIFIC OBJECTIVES**

The goal of this research was to expand knowledge about skill learning and transfer. The aim was to develop and test a theory of transfer with specific emphasis on visually supported flight skills.

### **APPROACH**

Relatively little is known about the nature of fundamental skills underlying complex real-world tasks or how those skills are learned. The expertise of aircraft pilots was selected as a domain of suitable complexity and relevance. This research program was initiated with a review of the issues facing flight instruction. That review (Lintern, 1995) suggested several areas that were ripe for investigation, one of which related to the type of information used in piloting an aircraft and how pilots developed sensitivity to that information during flight instruction. The specific tasks of landing a light aircraft and of navigating an aircraft through an unfamiliar area were selected for intensive study.

The experimental projects undertaken in this program used a flight simulation system developed around a real-time computer-generated visual display. Two experimental paradigms were exploited. One was used to explore the visual information and skills used to support the aircraft landing task. As a means of identifying critical sources of information, experiments with experienced pilots examined how distortions in the simulated visual scene affected landing performance. The second paradigm evaluated transfer in a mission rehearsal task. A navigational database was developed and displayed via the visual simulation system. Flight students were taught navigational skills under different experimental conditions and were then tested in a realistic navigation condition.

### **PROGRESS**

The landing work identified a number of the properties in a visual scene that pilots use for guidance and control of the aircraft (Doherty, 1996). The experimental work in this project has shown that there are a number of sources of information that can be used for guidance of a landing approach but that texture offers the richest and most readily usable source. Pilots function moderately well in the absence of texture, but the presence of texture enhances the accuracy and stability of control during the approach to landing. As further confirmation that texture has an important role, a mathematical analysis of texture gradients was used to establish that those gradients could, in principle, guide an approach to landing (Lintern, submitted).

The Mission Rehearsal research has shown that interactive, real-time mission rehearsal is better preparation for a navigation task than the normal forms of preparation by map study (Bone & Lintern, in press). In addition it has shown that high workload during rehearsal can reduce the effectiveness of the method of preparation and that the



richness of the visual environment has an effect on how useful mission rehearsal is for a visual navigation task (Gorton, in preparation).

### CONTRIBUTIONS TO BASIC SCIENCE

This research program has made contributions in the areas of visual perception and skill transfer. While visual perception is one of the more heavily researched areas of the psychological sciences, there remains a dearth of knowledge about visual information used by operators of complex systems. There is essentially no complex control task for which there is an empirically demonstrated taxonomy of visual properties that support control behavior. This project demonstrated that some of the properties examined in basic visual science apply to the complex control task of landing an airplane.

Within the area of skill transfer, there is general agreement that transfer is based on similarities between training and transfer tasks. There is, however, no consensus on the nature of these similarities. An assumption underlying the project is that critical visual properties which support flight control constitute an important subset of those critical similarities. Thus, this work was aimed at identifying visual properties that support flight control and examined some aspects of how they are implicated in transfer.

### POTENTIAL APPLICATIONS

Many of the problems in learning to fly result from the difficulty of acquiring new perceptual skills and specific control strategies. The results of this work could enable the development of part-training strategies that will speed the acquisition of flight skills and that will guide the design and use of training simulators.

The research on mission rehearsal is the first to show that this method of familiarization can develop transferable skills. Mission rehearsal is a procedure that has received considerable publicity in recent years and is likely to be widely implemented within the US military. The research in this program engenders confidence that mission rehearsal will benefit operational performance. In addition, the research demonstrates some aspects of how a program of mission rehearsal can be evaluated.

### PROJECT REPORTS

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- Lintern, G. (1997). *An analysis of slant for guidance of landing approaches*. Manuscript submitted for publication.
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## **Selective Interference In Visuo-Spatial Memory**

Contract #: N68171-95-C-9122  
Institution: University of St. Andrews,  
Fife, Scotland

Contract Dates: 8/95 - 8/97  
PI: John Quinn

### **SCIENTIFIC OBJECTIVES**

Research into the visio-spatial component of working memory is considerably less advanced than research into the verbal component. It requires a robust technique that can be used to cause selective interference in selection, encoding and retrieval that will allow its particular attributes to be investigated. Without a method of measuring selective interference, the properties of visual memory can not be isolated.

This research will develop and exploit a robust technique that will allow the investigation of visio-spatial memory by selectively disrupting visual memory at specific anchor points. One is a type of visual display which, when presented as irrelevant to an ongoing task, will cause no interference. The second is also a display type that will cause selective interference and we know a display type that will cause general interference. With these points, it is possible to search for the dimensions which are crucial for determining selective and general interference in visual memory.

### **APPROACH**

The experimental investigations will fall into two groups: one group will concentrate on the contrast between displays that cause no interference and those that interfere selectively with visual memory. Another group will concentrate on the distinction between displays that cause selective interference and those that cause general interference.

Group One: The difference in the visual displays that cause no interference and those that cause selective interference is slight: static and dynamic noise respectively. A series of experiments will use the contrast between static and dynamic noise as the starting point and systematically vary the parameters of the displays in an effort to determine the features crucial for selective interference.

Group Two: There is some evidence that the predictability of an interfering display plays a part in causing general, non-selective interference. In the group two experiments, predictability within a presentation sequence will be varied and its effects on the nature of interference determined. To ensure a controlled change in predictability, matrices and geometric patterns will be initially used. Such patterns can be changed in a step by step fashion and, therefore, predictability controlled. Additionally, they share features with the noise displays and so allow points of contact between the experiments in both groups. A final series of experiments will incorporate elements of both groups and will consist of a presentation of the interfering displays during the maintenance of the main task as well as during its presentation.

## PROGRESS

Research to date confirms the robustness of dynamic visual noise in causing selective interference with density parameters of the display important in the degree of interference caused.

Evidence thus far also suggests that with displays other than dynamic visual noise, the timing of the interference rather than its predictability is crucial in causing general interference. Future experiments will increase sensitivity to the importance of the timing of the presentation with the displays we choose; they will also integrate the timing parameters with other aspects of the design of the visual displays to develop a more comprehensive account of the nature of interference in visual memory

## CONTRIBUTIONS TO BASIC SCIENCE

Theoretical research into the visio-spatial component of working memory has been hampered by a lack of valid methods for inducing selective and general interference. This project will further validate and demonstrate the potential of the method of causing general and selective interference. The research and the techniques being used are already stimulating many more investigations of the theory of visio-spatial working memory and allowing the further delineation of the model of Working Memory .

## POTENTIAL APPLICATIONS

The research will allow more empirical research in the area of terrain visualization and other environments requiring situation awareness. The method is relevant to the presentation of visual information in, for example, computer displays, especially when such displays are rapidly up-dated. The method also holds promise of leading to perceptually based methods of training such visual and spatial tasks as target identification and map reading and following.

## **RACO RESEARCH OBJECTIVE #2:**

***Provide fundamental knowledge to guide the development and assessment of small team leaders.***

Research in this section is geared towards determining the effectiveness of team leadership as a function of leader behavior and team goals.

## ***Ongoing Research***

## **Platoon Readiness as a Function of Transformational/Transactional Leadership, Squad Mores, and Platoon Cultures**

Contract # DASW01-96-K-0008  
Institution: State University of New  
York at Binghamton

Contract Dates: 8/16/96-7/31/99  
PI Names: Bernard M. Bass &  
Bruce J. Avolio

### **SCIENTIFIC OBJECTIVES**

The primary goal is to predict the leadership performance of platoons going through the Joint Readiness Training Center. Transformational and transactional leadership theory is used as a basis for formulating predictions in the current investigation. It is expected that the performance of platoons would be higher if the leadership in the platoon when evaluated by multiple sources (superior, peer & subordinate) is more transformational (charismatic).

### **APPROACH**

360 evaluations using the Multi-factor Leadership Questionnaire (MLQ) of the platoon commander and sergeant were collected in garrison generally one to two months prior to each platoon attending JRTC. Evaluations of the platoon's collective leadership profile and culture were also gathered in garrison from different rater sources in the platoon, in order to reduce the effects of common source bias. Platoon commanders were rated by the CO, XO, CO-sgt, sgt, peers from two other platoons in their company and subordinates within the platoon, including squad leaders, fire team leaders, and squad members. Sergeants were rated by the CO, XO, CO-sgt, peers from two other platoons in their company and subordinates including squad leaders, fire team leaders, and squad members. Ratings of collective leadership and culture were based on the same dimensions/constructs contained in the MLQ, escalated to a group and company level of analysis. For example, measures were taken of the platoon's collective transformational leadership using the Team Multi-factor Leadership Questionnaire (TMLQ), as well as whether the platoon had a transformational culture using the Organizational Description Questionnaire (ODQ).

Performance in JRTC was evaluated by observer-controllers (OC's), who accompanied the platoons carrying out their assignments over a two-week period. A survey measure was developed to assess the platoon leader's performance, sergeant's performance, their ability to work together in the field and the platoon's overall performance. The criterion evaluation measure was developed by a consulting team who had extensive experience in the military, working in conjunction with the two PI's. OC rater input was also solicited in the development of the criterion measure.

The criterion data collected at JRTC assessed the platoon's readiness and consistency of the platoon commanders' and sergeants' leadership with Army policy governing combat leaders. Ratings by the OC evaluators were collected at three points during JRTC, following the completion of each of three phases.

Modifications to all of the surveys were made following initial pilot data collection. Revisions were done in order to clarify items in both the predictor and

criterion measures, and to drop items that did not contribute to the respective scales internal consistency.

Response rates for both the leadership and criterion measures have been consistently high at each of data collection sites. Data have been collected thus far according to the following totals: 72 platoons, 72 platoon leaders, and for 72 platoon sergeants. A total of 2,136 respondents participated in this study as of August, 1998. Respondents belonged to 4 brigades.

## PROGRESS

Data has now been collected on 54 platoons, which have gone through JRTC training, and 18 platoons that went through NTC. An additional 18 platoons will participate in the final data collection this February 1999. Following the collection of all of the predictor and criterion data, a total of 90 platoons will have participated in this project. Data on the additional 18 platoons is being collected to bring the total number of platoons who have gone through JRTC to 72.

Analyses of survey instruments collected in Garrison and at JRTC have been completed within each sample, as well as for the total sample ( $n=72$  platoons). Using the MLQ and TMLQ surveys collected in garrison, exploratory factor analyses with the first data set have been conducted to identify the constructs underlying each of these survey instruments. Competitive models were tested based on prior work using these survey instruments with civilian samples (Avolio, Bass, & Jung, in press 1999). A six-factor model of leadership was found to have the best fit for the data collected with the MLQ. The six factors corresponded to earlier results reported for civilian samples. The six factors were the following: Inspirational, Intellectual Stimulation, Individualized Consideration, Contingent Reward, Active Manage-by-Exception and Passive-Avoidant Leadership. The six-factor model was strongly confirmed in the second set of samples using confirmatory factor analysis.

Exploratory factor analyses with the TMLQ produced a similar factor structure, except that Individualized Consideration and Contingent Reward loaded on a single factor, thus producing a 5-factor model. The 5-factor model was strongly confirmed in the second set of samples.

Analyses of the criterion measure demonstrated that factors comprising this measure were as intended in terms of measuring platoon commander, sergeant and the overall leadership performance of the platoon. In the initial data set, high internal consistency reliability allowed us to trim some items to reduce the amount of time taken by the OC raters to complete the form without any loss of reliability.

Some of our preliminary findings with 54 platoons that have gone through JRTC indicated that the transformational leadership ratings of platoon commanders and sergeants collected in garrison did significantly predict the performance of the platoon at JRTC. Preliminary findings indicate that the level of predictive validity varies by rater source, with the commanders' ratings of the target leaders being most predictive of overall performance at JRTC. Specifically, platoon leaders who were evaluated as more transformational, using more contingent reward and were less passive-avoidant led platoons with higher performance at JRTC. A similar pattern was also found for the

sergeants leadership performance. Other rater sources varied in terms of their predictions of performance at JRTC, partially confirming the above findings.

Exploring some of the qualitative data reported by OC's at JRTC, we have found that the quality of the relationship exhibited between the platoon commander and sergeant was markedly different comparing the top versus bottom performing platoons. The top performing platoons had platoon commanders and sergeants who exhibited, throughout the 2-week period, a more active and transformational leadership relationship.

### CONTRIBUTIONS TO BASIC SCIENCE

Results to date support some of the basic propositions in transformational and transactional leadership theory. Specifically, we have been able to separate out at least 6 factors that represent the components of transformational and transactional leadership. Leaders exhibiting more transformational leadership not only received higher ratings of satisfaction and effectiveness in garrison, they also performed better as individuals and as an overall platoon at JRTC. Linkages of the quantitative results to patterns in the qualitative data collected at JRTC is offering some unique insights into what leaders do, as well as how frequently they do it, to be rated by others as transformational.

### POTENTIAL APPLICATIONS

The findings clearly support the utility of transformational and transactional leadership theory for use in military settings for predicting the readiness of units. Results indicated that selecting and developing leaders who are more proactive and transformational should show up in both how effective the platoon is in garrison, as well as under extreme conditions such as JRTC. Also, we have been able to develop a highly reliable criterion measure that can be used in other research on Army units.

## **Inter-Activity, Communication, and Trust: Challenges and Opportunities for Leadership in the Electronic Age**

Contract #: DASW01-98-K-0009  
Institution: University of Arizona

Contract Dates: 9/15/98-9/14/00  
PIs: Judee K. Burgoon, Joseph A. Bonito, & Suzanne Weisband

### **SCIENTIFIC OBJECTIVES**

Two related research programs are examining the effect of communication technologies on communication process and outcomes, leadership, and team performance. The first, headed by Dr. Judee Burgoon, is concerned with inter-activity. Inter-activity can be described as a property of the communicative exchange that varies according to degree of interdependence and responsiveness of communicators' messages to one another (Rafaeli, 1988), i.e., it entails multiple, tightly interwoven conversational exchanges and a sense-making process that implicitly references not only immediately adjacent but infinitely prior messages. Objectives are stated below:

1. How do properties of inter-activity affect leader-follower perceptions, communication processes, and task performance? What essential properties of inter-activity need to be retained, simulated, or augmented when choosing a communication format or developing new behavioral technologies, when effective leadership is the goal?
2. How do leaders and followers develop their knowledge of each other and of the specific task through face-to-face and electronic team interaction?

The second line of research is under the direction of Dr. Suzanne Weisband. It is concerned with how the rapid and pervasive diffusion of new communication technologies, coupled with increased emphasis on distributed teams and teamwork, is fundamentally transforming the modern military. With these changes have come new challenges and opportunities for the exercise of leadership.

The two-pronged research program we are proposing addresses the following questions:

3. How can team trust be established or maintained when team members do not interact face-to-face (FtF)? What effect will initial FtF or mediated team interaction have on subsequent team performance?
4. Can leaders be trained to motivate distant team members communicating electronically to perform their best, that is, to raise the team's collective efficacy so that they feel confident that they can accomplish the task successfully?

### **APPROACH**

Inter-activity Research Program. We proposed a series of experiments to examine how various computer technologies and participant conditions augment or attenuate processes and features of inter-activity, as well as explore the effects of media on task-related outcomes. Media and participant conditions were chosen and manipulated according to



theoretical tenets. Participants were to collaborate on a decision-making task with trained confederates in one of four conditions: face-to-face, text-only, audio and visual, and audio-only. In addition, participants in another condition were to observe videotape of previous interactions and asked to rate them. Dependent measures focused on influence, quality of decision making, and assessments of communication process, participants, and outcomes, including, trust, perceived similarity, credibility, competence, task attraction, utility, and ease of interaction.

Team Development Research Program. Graduate and undergraduate students in two geographically distant U.S. universities participated in virtual team projects developed for their MIS classes. While the classes at the two universities differed in a number of ways, the project was designed to simulate work in temporary virtual teams: (1) The project lasted 4 weeks; (2) vulnerability was high as the task was highly interdependent and required team interactions to achieve objectives; and (3) uncertainty was high as everyone was a stranger and all communications were to be conducted using some form of mediated communication. To enable fair participation across the two universities, the project started and stopped on the same dates, students were given the same project instructions, requirements and deadlines. Teams were comprised of four members, where one of the members was a graduate student assigned as the team leader.

In an effort to analyze strategies for interaction, we focused on the actual communication in context. Strategies associated with initiations and responses were also analyzed as way of measuring trust. To initiate interactions requires trust. It places the initiator in a position of vulnerability. Generating the relevant responses also indicates trust. A response indicates to the initiator (and everyone involved in the interaction) that the receiver has done his or her obligatory part. Consequently, the making of responses signals and inspires trust that the group is responsible and skillful enough to handle the uncertainties currently in front of them.

In addition to the electronic messages, we collected data from pre- and post-project questionnaires, measuring demographics, school performance, computer access, team and electronic communication experience, and perceptions of leadership. Team performance was a reflection of the team grade as mutually determined by the professors.

## PROGRESS

Inter-activity Research Program. Two sets of data were collected during 1998. Preliminary results suggest that characteristics of communication technology affected the degree to which participants were influential, viewed as competent, and felt involved in the interaction. The findings were presented at the Hawaiian International Conference on Systems Sciences in two separate papers:

Burgoon, J. K., Bengtsson, B., Bonito, J. A. , Ramirez, A., & Dunbar, N. (1999).  
Designing interfaces to maximize the quality of collaborative work.  
Proceedings of the 32nd annual meeting of the Hawaiian International  
Conference on System Sciences, Maui. IEEE.

Bengtsson, B, Burgoon, J. K., Cederberg, C., Bonito, J. A., & Lundeberg, M. (1999, January). The impact of anthropomorphic interfaces on influence, understanding, and credibility. Proceedings of the 32nd annual meeting of the Hawaiian International Conference on System Sciences, Maui. IEEE.

We are currently revising and refining our studies for publication. The remaining experiments are currently in the planning stage with data collection tentatively scheduled to begin in Spring, 1999.

Team Development Research Program. We designed and completed all data collection for the first round of the quasi-experimental field work. Our first study is now in the process of analysis and refinement, and two papers were submitted to two conferences, where preliminary findings will be presented.

Weisband, S. & Woodard, J. Perceptions of Leaders at a Distance. Paper to be presented at the Society for Industrial and Organizational Psychologists (SIOP). Atlanta, Georgia, April 1999.

Weisband, S., Iacono, S. & Gilliam, A. Trust and Monitoring: Predicting Successful Outcomes in Distant Teams. Symposium on Trust in Distributed Teams submitted to the Organizational Behavior and Organizational Communication and Information Systems Divisions of the Academy of Management, Chicago, Illinois, August 1999.

Our second study was designed to investigate the effect of (1) early team building activities (early team interactions vs. no early team interaction) on subsequent performance, and (2) early communication modality (face-to-face vs. asynchronous computer communication) on subsequent performance. Our research design for the pre-project task is:

Group	Communication Modality	Early Team Building
Experimental Group 1	Face-to-Face (n=8)	Team Building Task
Experimental Group 2	Computer (n=8)	Team Building Task
Control	No interaction (n=7)	Individual Task

#### CONTRIBUTIONS TO BASIC SCIENCE

Inter-activity Research Program. We are just starting to understand the processes by which people adapt to and interact through communication technologies. It is clear that some technologies transmit more digital and analog information than others. Analog information refers to nonverbal behavior and contextual cues that allows participants to develop more complete representations of individuals and communication process. Increasing analog information creates a richer communication environment that creates more positive impressions of the task and interlocutors, and might well lead to increased influence.

Team Development Research Program. The results of this research should have direct implications for current organizational theories that address distributed "virtual" processes for accomplishing work. As work becomes more global and distributed, the whole nature of organizing will inevitably be challenged and modified. Such changes need to be guided by systematic empirical work rather than by anecdote and personal experience, which in many quarters form the primary source of "data." The longitudinal field work closely resembles the kinds of work contexts faced by members of the same organization and members of teams assigned to projects with distant others.

#### POTENTIAL APPLICATIONS

Inter-activity Research Program. Our data suggest that interface and communication technology designers should first establish the kinds of process and outcome goals that are important to their projects. Careful consideration of these issues will allow the design of technologies that either increase the degree to which persons involved in computer-mediated communication feel connected or similar or increase the likelihood of clear and direct communication designed especially to influence.

Team Development Research Program. This field research will provide a unique opportunity to learn what it takes for distant teams and leaders to be successful by analyzing the actual interactions among virtual team members. It will reveal what communication practices are needed to create and sustain trust. A natural outgrowth of this work should be the development of training procedures for leaders in mediated settings. Other potential applications will be to develop software that will create a more visible form of social awareness for team members and leaders who cannot communicate face-to-face.

# **Information Management in Distributed Command and Control Organizations.**

Contract #: DASW01-95-C-0156  
Institution: ALPHATECH, Inc.

Contract Dates: 9/30/95 - 9/29/99  
PI: Elliot E. Entin

## **SCIENTIFIC OBJECTIVES**

The major objectives of this project are to develop and test: 1) a cognition-based theory of information management applicable to information-rich, distributed command organizations; 2) a taxonomy of critical skills and knowledge requirements for producing effective information management processes; 3) a training program that enhances decision makers' ability to manage large amounts of information more efficiently and effectively and to reduce the errors that may occur in handling large amounts of information. A related objective of this work is to investigate the impact of emerging information distribution technologies on  $C^2$  organizations. We hypothesize that the increased availability of large quantities of information to individuals at all levels in an organization will decrease reliance on traditional, hierarchically based channels of communication, and thereby cause a de facto 'flattening' of hierarchically structured organizations. We also hypothesize that a deeper knowledge of organizational structure will facilitate information management processes by helping individuals to filter and distinguish information according to the requirements of the particular organization. We define information management as the set of cognitive processes and behaviors that include the receiving, integrating, filtering, processing, seeking, and exchanging of information by an individual decision maker in an organization.

## **APPROACH**

One component of the approach is the development of a model of information management based on theoretical considerations and on empirical observations made in naturalistic settings. This model enumerates the knowledge and skills required for effective and efficient information management, and serves as a basis for the experimental and training components of this project. The second component of our approach experiments provide a complementary way of identifying requirements for a training program for managing information overload. They can be used to assess the impact of information overload on information managers; observe and identify skills and knowledge decision makers use when seeking, filtering, and exchanging information; and investigate the impact of knowledge of organizational structure on information management. Our approach is to experimentally identify the critical skills and knowledge requirements for effective information management training needs, and explore how people deal with large amounts of information, and determine what errors are commonly made in handling information overload. It will also explore how knowledge of organizational structure affects information management. Based on our model and experiment, as well as on other relevant empirical findings and theoretical developments, the third component of the project is to develop a training program that will help decision makers deal effectively with large volumes of information, both in terms of efficient and effective processing of incoming messages and in minimizing the volume and

maximizing the effectiveness of outgoing messages that they generate. The training program will use a scenario-based approach and will include the four basic components required for any successful training program: lecture, demonstration, practice, and feedback.

## PROGRESS

We developed a cognition-based model of information management, and conducted an experiment to empirically identify information management strategies, techniques, and skills that are amenable to enhancement through training. Our model of information management provides a framework to link typical information management processes faced by a decision maker (e.g., receiving, filtering, fusing, assessing, transmitting information). In addition to decomposing the information management process, it identifies typically observed errors in naturalistic settings, and suggests general approaches for remediation. It also identifies a subset of critical skills, behaviors, and knowledge bases that are most amenable to training. The model is being used as a hypothesis generation device for performance assessment and training experiments conducted in this project.

We conducted an experiment in which we systematically assessed information handling under two levels of information load and two levels of knowledge about organizational structure. In all conditions information arrived electronically, by phone, and written messages. The experiment was conducted using our dynamic distributed decision making simulation with a joint-service scenario. Sixteen military officers served as subjects. Each subject participated in two trials, one under low- and one under high-information load. During the experiment trial, the subjects processed incoming messages, sent out messages to and requested information from other nodes in the organization, and formed an assessment of the situation. Subjects rated the criticality of each message they processed. At the end of the trial, subjects provided a written and an oral assessment of the situation.

As hypothesized, we found that participants attained significantly higher scores ( $p < .01$ ) for each of the four situation assessment accuracy items when information load was low than high. Clearly high levels of information load negatively impacted participants' ability to perform a situation assessment task. The analyses revealed that participants performed better in the deep than shallow organizational knowledge condition when information load was low ( $p < .05$ , one-tail). We hypothesized that deep organizational knowledge would be especially important when information load is high. Thus, there is some evidence that deep organizational knowledge can enhance performance when information load is high.

Participants rated each incoming message in terms of its criticality to their mission. Results show that participants were not accurate in discriminating between critical and non-critical messages in either information load condition. Within each information load condition, participants were about equally likely to rate noncritical messages as critical as they were to rate critical messages as noncritical. A second important finding is that in both conditions participants overrated the number of critical messages.

In the experiment participants could send messages to any node in the organization. We examined the correctness of node destination (i.e., was the message sent to the appropriate node level in the organization). Participants were most accurate in the messages they directed to superiors and least accurate in the messages directed to subordinates.

### CONTRIBUTIONS TO BASIC SCIENCE

This project contributes to the development of a theory of information management. It enumerates a taxonomy of information management skills and provides a structural framework under which they are organized. It develops theoretically and empirically-based principles and methods for training information management skills and knowledge in distributed decision making organizations. The development of a theory based and empirically validated training program contributes an initial step toward a science of distributed training. The work will also contribute to an understanding of the interactions between information flow and organizational structure.

### POTENTIAL APPLICATIONS

The theory of information management and the training program that is developed are applicable in both military and non-military information-rich environments in which individuals are required to filter high volumes of electronic and/or telephone messages. The information management principles and techniques are applicable to automated as well as human information processors. Furthermore, the organizational structure and message set can be used as a testbed for automated information agents that are developed to find, comprehend, integrate, and distribute information in an organization composed of intelligent (human and automated) agents.

# Identifying the Abilities Involved in the Acquisition of Tacit Knowledge

Contract #: DASW01-98-M-2036  
Institution: Yale University

Contract Dates: 9/15/98 – 9/14/99  
PI(s): Jennifer Hedlund & Robert J. Sternberg

## SCIENTIFIC OBJECTIVES

The primary objective of this one-year research project is to understand the processes underlying the acquisition of knowledge that is characterized as tacit. The term *tacit knowledge* is used by Robert Sternberg and his colleagues (Sternberg, 1997; Sternberg, Wagner, Williams, & Horvath, 1995) to characterize knowledge that is acquired on one's own, procedural in nature, and instrumental to achieving one's personally valued goals. Tacit knowledge is viewed as one aspect of practical intelligence that distinguishes individuals who are more from those who are less successful. Individuals who are able to learn effectively from their experiences and apply their knowledge to the solution of real-world problems, should have more success in dealing with the types of practical tasks they experience in their everyday lives.

In the present research, we focus our attention on the tacit knowledge that distinguishes military leaders who are more from those who are less effective. In our previous work, we identified examples of tacit knowledge in the stories and advice that leaders shared about their experiences, developed instruments for measuring the possession of tacit knowledge, and obtained evidence that tacit knowledge relates to effective leadership (Hedlund et al., 1998; Sternberg et al., in press). The purpose of the present research is to understand why some leaders learn more effectively from their experiences than others. To address this issue, we seek to identify the cognitive processes that support the acquisition of tacit knowledge. Our efforts focus on three key knowledge-acquisition processes: selective encoding (the ability to extract relevant information from the situation), selective combination (the ability to integrate information into a meaningful interpretation of the situation), and selective comparison (the ability to relate new information to existing knowledge).

## APPROACH

Our approach to understanding tacit-knowledge acquisition involves measuring the use of knowledge-acquisition processes in solving practical leadership problems. We present written descriptions of the types of situations encountered by leaders and ask participants to provide responses to those situations. Most of the situations are taken from the tacit-knowledge inventories developed in our previous work. The responses will be in one of three forms. Format A asks participants to rate the quality of several options for addressing each situation. This is the format used previously to measure tacit knowledge and provides a standard for comparing answers based on the new formats. Form B is an open-ended, unstructured format, and asks participants to provide their own responses to each situation. Format C is an open-ended, structured format, and asks participants to respond to a set of question prompts aimed at assessing their problem-solving and knowledge-acquisition skills. For example, "What do you see as the problem



in this situation?” assesses problem recognition and definition; and “What information did you use to formulate your strategy for addressing this problem that is in the statement of the problem above?” assesses selective encoding. Responses to Formats A and B will be scored against an expert standard developed from previous research. Responses to Format C will be rated according to how well the leader addresses each question. We will compare responses on the different forms to determine the extent to which (a) leaders are able to use the information in the problem description to arrive at an effective and appropriate solution, and (b) leaders who arrive at an appropriate solution engage in more effective problem-solving and knowledge-acquisition processes.

### PROGRESS

During the first five months, we have developed the questions for Formats B and C and have selected a set of candidate problems to add to the existing scenarios included in our Tacit Knowledge Inventories for Military Leaders (TKML). We had planned initially to develop a limited number of in-depth leadership cases to present to a small sample of participants and ask them to provide written responses to those cases. In the process of developing our measure, and in response to feedback from ARI and Army personnel, we decided to use the formats described above. These changes have allowed us to include more items and to administer the survey to a larger sample of military leaders. Consistent with previous work, we have developed three versions of the survey, one each for platoon leaders, company commanders, and battalion commanders. We decided also to administer the survey electronically, via a web site on the internet. We have a test version of the survey for platoon leaders (with Format A and B questions) on-line. We are circulating the candidate questions for Format C among military experts for comments and suggestions. The complete surveys are expected to be on-line by the end of February and data collection to begin by March.

### CONTRIBUTIONS TO BASIC SCIENCE

Our research addresses the basic question of how people acquire tacit knowledge. In previous research we have shown that tacit knowledge is relevant to successful performance in a number of domains, including business management, education, and most recently military leadership (Hedlund et al., 1998; Sternberg et al., 1995). So far these efforts have focused on measuring existing knowledge, not necessarily the ability to acquire tacit knowledge. Furthermore, they have focused more on establishing the relationship of tacit knowledge to performance, than on identifying ways to develop such knowledge. By measuring how leaders interpret and respond to realistic leadership situations, we hope to obtain preliminary insight into the processes that are associated with the effective acquisition of tacit knowledge.

### POTENTIAL APPLICATIONS

The findings of this research will have potential implications for both the measurement and development of tacit knowledge. In terms of measurement, we will have developed a preliminary tool for assessing the practical ability underlying tacit-knowledge acquisition. This tool can be further evaluated in relation to other measures of leadership effectiveness to determine its relative contribution to understanding successful

performance. In terms of development, we will have potentially identified key processes associated with tacit-knowledge acquisition that can be fostered in all leaders. That is, leaders can be given instruction on the specific processes that are useful for learning from experience and they can be given opportunities to practice using these skills.

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# Knowledge-Driven Decision-Making - A Pilot Study

Contract #: MIPR8MDSG98050  
Institution: University of Haifa

Contract Dates:  
PI: Raanan Lipshitz

## SCIENTIFIC OBJECTIVES

This is a pilot study for a multi-year project with four objectives: Developing a model of knowledge-driven decision-making, studying the development of proficient complex decision-making, developing a methodology for improving decision-making skills, and tackling the dilemma of rigor vs. relevance in the study of decision-making. The objectives of the pilot study are to design and test operationalizations for mental models and decision strategies in the micro-world (computer driven behavioral simulation) that will be used in the multi-year project (Gettysburg!), to develop an initial set of hypotheses for that project, to design and validate its data collection method, and to train research assistants.

## APPROACH

### Operationalization of mental models:

A three stage method will be used to develop a structured format for representing players' mental models of the situation in Gettysburg!. In the first stage players will be asked to provide think aloud descriptions of the situation, paying particular attention to those aspects which they consider particularly important for their position, their actions, and the likelihood that they will win the battle. Think aloud protocols will be audio-recorded, and an experimenter will take hand-written notes for use in a post-session debriefing aimed at clarifying potential ambiguities. In the second stage protocols will be transcribed and coded for repeated themes (e.g., threats, opportunities, goals, expectations, action implications). Using a criterion of stability, those aspects which appear consistently across different players and proficiency levels will be used as the basic aspects of players' mental models. Since protocols will be taken from subjects at different levels of proficiency, it may be possible to select aspects on the basis of a second criterion, sensitivity to proficiency level. A semi-structured interview format will be developed in the third stage as an alternative for the think aloud method which is cumbersome, intrusive, and extremely labor intensive.

### Operationalization of decision strategies:

An argument analysis method developed in a previous research using a simpler micro-world (Winmoro) is also applicable to Gettysburg! A limitation of this method is that it is purely descriptive. To overcome this limitation the pilot will also develop a strategy-quality evaluation scheme. An initial pool of quality criterion will be generated by searching the Internet sites which provide advice for Gettysburg! players (the game is fairly popular and several sites run by experienced buffs can be found on the Web). The pool will be trimmed to a workable set of criteria summarized in a form of detailed manual for evaluating players' decision quality.

### PROGRESS

The project is still at launching stage (installing the software, recruiting subjects, designing the procedure for data collection).

### CONTRIBUTIONS TO BASIC SCIENCE

The pilot study is not expected to contribute to basic science. The multi-year project is expected to further our understanding of how decision making is driven by decision makers' mental models, that is, their, concrete, semantic representations of their situations and how mental models and decision strategies change concomitantly as people improve their proficiency in tackling complex decision making tasks.

### POTENTIAL APPLICATIONS

The multi-year project will serve as a test-bed for the use of micro-worlds for decision training.

# **Leadership, Team Cognition, and Team Performance: The Development and Influence of Leader Mental Models on Team Mental Models and Team Performance Regulation.**

Contract #: DASW 01-96-K-0002  
Institution: George Mason University

Contract Dates: 4/25/96-9/30/99  
PIs: Stephen J. Zaccaro &  
Richard Klimoski

## **SCIENTIFIC OBJECTIVES**

Leadership and team performance are critical elements of military effectiveness. Yet, despite vast literatures on leadership and team dynamics, respectively, there is surprisingly little conceptual research on precisely how leaders create and direct team processes to achieve collective success. Two fairly recent developments in both leadership and team performance research have provided a basis for developing a conceptual framework that specifies the critical components of effective *leader-team* performance. One is a perspective that defines leadership as discretionary problem solving directed toward the facilitation of team and organizational goal attainment. Such problem solving involves the development of mental models that facilitate a leader's understanding of different problem domains, the subsequent derivation of effective solutions, and the leader's interactions with their team. A second development is the increasing application of cognitive theories and models to team performance. For example, Cannon-Bowers and her colleagues have argued that effective team coordination and performance depends upon the emergence of accurate *shared mental models* of requisite team strategies and interaction tactics among team members (Cannon-Bowers & Salas, 1990; Cannon-Bowers, Salas, & Converse, 1993).

Based on these developments, the scientific objectives of the present effort were to measure, examine and describe the influence of leader mental models and leader communications on the development of team mental models, and subsequently on team coordination and performance. These influences were to be explored in both laboratory and field settings. Also, because there is a lack of conceptual perspectives integrating both leadership and team dynamics, another objective of this research effort was to convene a conference of scholars who have completed research in either or both of these domains. The intent of this conference was to explore and discover different perspectives on leader-team performance.

## **APPROACH**

This research effort is composed of both experimental and field studies, as well as the conference. Two experimental studies were used to investigate how leader communications influence the emergence of team mental models. In the first study, we manipulated the content of leader briefings and observed the effects on emergent team mental models, team processes and team performance. In the second, we examined how leader sensemaking processes were related to the quality of team mental models and team performance. The field studies were designed to examine team mental models in hierarchical Army teams in training settings. A major task in this effort was the construction of measures to assess leader and team mental models in natural settings.

One study, completed with an Army command and control team at Ft. Rucker, examined mental models of appropriate communication patterns during various stages of a digital battle training exercise. The second study, completed at Ft. Knox, was designed to yield a measure of team mental models of military decision making under different battle conditions. This measure reflected the METT-T decision model that is the basis for training Army tank platoons.

The conference was designed to facilitate discussions among leadership and team scholars around specific themes. The conference format included four speakers: Richard Klimoski, Richard Moreland, Fran Yammario, and Paul Goodman. It also included 7 working groups that considered several themes related to the influence of integrated leader/team processes on work effectiveness.

### PROGRESS

The data from both laboratory studies have been collected. Results from the first study indicated that (a) the quality of leader briefings increased the degree to which performance mental models were shared among team members, as well as the accuracy of these models, and (b) shared mental models facilitated team adaptation to aversive circumstances. Data from a training exercise at Ft. Rucker were collected and are currently being analyzed to examine the influence of mental models regarding team communication on team performance. Data were also collected regarding the influence of communication efficacy on team adaptiveness to adversity. Preliminary analyses demonstrated that more efficacious dyads were better able to respond to increasing adversity in performance conditions. We have collected data at Ft. Knox to provide preliminary evidence for a prototypic measure designed to assess team mental models in a tank platoon. The analysis of these data indicated that the developed instrument was found to be a viable method of measuring differences in the procedural, declarative, and conditional tactical knowledge of experienced and inexperienced platoon members.

The conference was conducted on September 26-28, 1997. A follow-up to this conference was to create a special issue of *Group and Organization Management* devoted to the interface of team and leadership processes. We are currently reviewing manuscripts submitted for this special issue.

### CONTRIBUTIONS TO BASIC SCIENCE

One product of this effort is a conceptual framework that integrates leadership and team processes to explain effective collective performance. Such frameworks are not common in either the team or leadership literature. Also, preliminary analyses from the laboratory study have indicated a significant influence of leader communications on the content and structure of team mental models. These results provide information on how team mental models develop, and specifically on the role of team leadership in such development. It is expected that the basic scientific contributions of this research will expand as the remaining studies are completed and the data from them analyzed for their implications.



## POTENTIAL APPLICATIONS

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. If validated, the measures of individual and team mental models that were developed respectively at Ft. Rucker and Ft. Knox, can serve as effective training assessment tools. Such tools can indicate where team members are weak in their understanding of requisite team processes and provide the basis for remedial interventions by trainers. The findings regarding the role of certain leadership processes that contribute to effective team performance can contribute to the development of curricula for use in early leader training programs.

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- Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan, Jr. (Ed.). *Current issues in individual and group decision making*. Hillsdale, N. J.: Lawrence Erlbaum.



# **Leadership, Team Processes, and Team Adaptation: The Development and Influence of Functional Leadership Capabilities of Team Adaptability to Adversity**

Contract #: DASW01-98-K-0005  
Institution: George Mason University

Contract Dates: 8/1/98-7/31/01  
PI: Stephen J. Zaccaro &  
Richard Klimoski

## **SCIENTIFIC OBJECTIVES**

Leadership and team performance are critical elements of military effectiveness. Yet, despite vast literatures on leadership and team dynamics, respectively, there is surprisingly little conceptual research on precisely how leaders create and direct team processes to achieve collective success. In particular, there has been little consideration in both the teams and leadership literature given to (a) the team cognitive, motivational, and coordination processes that specifically promote team adaptation; (b) how leaders influence the quality of these processes; (c) the personal qualities of the leader and of team members that promote team adaptation; and (d) leader and team training principles that specifically foster team adaptation.

The purposes of the proposed research program are (a) to examine in more detail the influences leaders have on team processes contributing to team adaptation, (b) to examine training and development principles that contribute to the development of adaptive military leaders and teams; and (c) to develop and examine the psychometric properties of a leader and team assessment tool that measures personal qualities contributing to adaptation. We propose to meet these objectives with a series of experimental and field studies in which we examine leadership and the motivational, cognitive, and coordination processes that contribute to team adaptation. We also intend to examine and validate integrated leader and team development guidelines that would foster these processes. Finally, our research efforts will also yield assessment tools designed to measure the influence of leader characteristics on leadership and team adaptability.

## **APPROACH**

This research effort is composed of both experimental and field studies. We are currently planning an experimental study designed to examine (a) leader and team attributes that promote flexibility and adaptation, and (a) training principles that foster the development of these attributes. The field studies are designed to (a) validate an assessment battery constructed to measure multiple attributes related to leader flexibility, (b) examine work experiences related to the development and emergence of attributes promoting leader flexibility, and (c) test training principles regarding the development of leader flexibility. We are planning to use the Army War College as a site for these field studies.

## **PROGRESS**

We are currently preparing the testbed for the experimental studies. Specifically, we are testing a new tank battle simulation that is more advanced from the one used in

previous research funded by ARI. Once this simulation is installed in our laboratory, we will be conducting cognitive and behavioral task analyses for the purpose of developing appropriate measures of individual and team mental models. For the field research, we have developed several conceptual models describing the influences of work experiences, formal instruction, mentoring and coaching processes, feedback systems, and self-development experiences on individual attributes related to leader flexibility. We have also developed an assessment battery that measures cognitive, behavioral, and dispositional attributes that foster leader flexibility. We have completed one pilot study in which we collected preliminary validation evidence. We are planning a second pilot validation study before preparing for a full data collection effort in the later summer and early fall. Finally, we are preparing coding protocols that will be used to code archival sources of work experience data. Our intention is to relate specific categories of work experiences to officer promotion. We will also use these data to construct a qualitative instrument to assess officer work experiences.

### CONTRIBUTIONS TO BASIC SCIENCE

One product of this effort is a comprehensive conceptual framework that describes a career-long process of leader development. This framework builds on previous research in the literature and incorporates multiple sources of developmental experiences (i.e., formal training, self-development, work assignments, mentoring, coaching, feedback). Accordingly, it is particularly appropriate for the U.S. Army. Also, the data from the planned laboratory and field studies should validate training principles regarding the efficacy of particular kinds of interventions. These data should also provide information regarding the development and influences of leader and team attributes that promote adaptability.

### POTENTIAL APPLICATIONS

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. If validated, the assessment battery measuring leader flexibility can serve as a very effective training tool in multiple Army training settings. Further, the field studies are expected to yield specific guidelines and curriculum tools that target the development of leader flexibility. These guidelines and tools are expected to be constructed in accordance with the different developmental needs that emerge at various points in an officer's career.

## ***Recently Completed Research***

# Factors Influencing the Effectiveness of Groups in Formulating Strategies to Achieve Goals

Contract #: MDA903-93-K-0016  
Institution: University of Maryland,  
College Park

Contract Dates: 9/1/93 - 10/30/98  
PI: Edwin A. Locke

## SCIENTIFIC OBJECTIVES

The goal of our research program was to study the relationship between group goals, group task strategies and tactics, and group performance. Extensive research shows that individual performance goals are critical determinants of individual performance on tasks, but group goal setting is less frequently studied. Individual studies have also found that task strategies are critical to group performance, especially on multi-path or on complex tasks where the best procedure for attaining the goal is not obvious. This issue also needs to be studied at the group level.

Our research addressed such questions as;

- (a) do the strategies groups develop in response to goals mediate the effects of group goals?
- (b) do the strategies that groups develop in response to leadership style mediate or interact with group goals?
- (c) do group goals affect the riskiness of the strategies groups pursue?
- (d) are group goals affected by task and incentive interdependence?
- (e) in field settings is group strategy development reactive or proactive?
- (f) in field settings do long term goals accompanied by short term goals lead to better strategies and performance than long term goals only?
- (g) in some of our studies we also examined the usefulness of the distinction between the concept of tactics and the concept of strategy.

## PROGRESS

Four laboratory and two field experiments were completed. In the first laboratory study using a "lost in the wilderness" task, we found that in a task situation where the group members did not possess sufficient information to validate their beliefs, the best tactic was to purchase information from outside the group. Groups with high goals were more likely to do this than groups with low goals. The effect of goals was mediated by this information-seeking tactic. Group strategy (in this case to stay with the downed plane--the correct choice-- or walk out) was independently predictive of performance. In the second laboratory study using Bolo, a computer tank battle simulation, we found that a leadership style that stressed group coordination worked better than a style in which the leader acted as a commander without input from group members. This coordinator style lead the groups to develop better tactics than the commander style. Group tactics interacted with group goals such that the best groups had both high goals and good tactics. In the third laboratory study, also using the Bolo simulation, we found that hard goals led subjects to attack riskier targets and more targets than was the case for easy goals. We also found that the use of the higher risk strategies led to better performance. Tactics were also related to performance. Incentive bonuses led to the use of better

tactics, the choice of less risky strategies for subjects with easy goals, and better performance for subjects with hard goals. The fourth laboratory study, also using Bolo, concerned goals people set and the tactics they used under different conditions or task and incentive interdependence. The alignment of degree of task interdependence with degree of pay interdependence did not facilitate performance. Cooperation between teams improved performance when there was high task interdependence. Goal difficulty and tactics significantly affected performance.

Our first field study, conducted by subcontractor Elizabeth Weldon, found that goal-directed production workers in a steel plant develop new strategies mainly in response to immediate problems rather than as a result of formal, advance planning. Furthermore, most of the ideas for strategies involved improved work procedures and came from individual members more than from group discussion. The second field study, also conducted by Dr. Weldon, used nursing inspectors as subjects. She found that giving the nurses short term as well as long term goals, as opposed to long term goals only, led to better performance and to more effective team strategies.

### CONTRIBUTIONS TO BASIC RESEARCH

We have made a number of contributions to basic research and theoretical knowledge. Our results show that theories of team effectiveness need to address the issue of knowledge seeking from outside the group. A group does not always have the needed information and cannot always get it through group discussion. Group goals are just as important as individual goals in influencing performance. However, group goals may work through their effects on group tactics or strategies or may work in interaction with tactics of strategies. Leadership style may affect group performance by means of its effect on group tactics. The distinction between strategies and tactics, which originated in the military, is also useful at the group level. Group goals affect risk-taking and tactics. This is the first time the issue of risk has been addressed in the goal setting literature. Much group planning in goal-directed teams is not formal but ad hoc; thus planning theories need to address this issue. Short term goals are critically important when groups are pursuing long term goals and work, in part, by stimulating strategy development.

### POTENTIAL APPLICATIONS

There are many practical applications of our findings. For example, group training should include training in how the group can decide what it really knows and how to decide if it needs information from the outside. This will help prevent inbred arrogance that often plagues groups, especially those which have been successful in the past. Second, we need to start thinking of leadership, in part, as a mechanism for helping groups to develop effective tactics and strategies. Although no one leadership style is effective in every situation, certain leadership styles may be better than other in particular situations for motivating group self-development. We found the coordinator style to be effective in the case where both the leader and the group were learning a new task requiring extensive coordination. Third, leaders need to be aware of the relation between goal difficulty and risk. If difficult goals promote more risk-taking, this is not necessarily bad; high risk actions sometime achieve spectacular results. However, the risk-reward relationship needs to be explicitly addressed. Fourth, if leaders want groups to do formal

planning, as opposed to just ad hoc planning, they will probably have to explicitly set aside planning time and a formal structure. Finally, leaders should insist that short-term goals be set as a means of insuring the achievement of any long term goals.

### **RACO RESEARCH OBJECTIVE #3:**

***As the Army evolves from a Cold War force to the 21st century, understand and anticipate the impact of societal trends and changes in the Army and its missions on soldiers.***

Research in this section describes and analyzes the effects of peacekeeping operations on soldiers, their families, and the Army. In addition, this research determines the effects of military involvement on the well-being and societal functioning of soldiers and their families.



## ***Ongoing Research***

## Leadership for Change

Contract #: N68171-98-M-5540  
Institution: University of Hull

Contract Dates: 6/98 – 12/99  
PI: Professor G. Harries-Jenkins

### SCIENTIFIC OBJECTIVES

The scientific objectives of this research are:

1. To review the characteristics of effective leadership styles and strategies in a period of change.
2. To conduct a comparative analysis of European policies, practices, and problems.
3. To identify and conceptualize models of good national policies and practices.

### APPROACH

Initially, a small group of technical specialists will meet at a workshop to establish a conceptual framework for the comparative analysis of leadership styles and strategies. Subsequently, these and four other specialists will be invited to participate in an extended workshop. This workshop will review the overarching theory and examine case studies based on specific national experience. Each of the technical specialists will possess considerable academic and professional experience in the doctrine and strategy of training in European military establishments.

### PROGRESS

The first workshop (planning) was held in Sep 98. It was agreed at the workshop that a twin-track approach would be most appropriate. One set of papers would focus on basic theories of leadership in Western military establishments in a period of change. A second set of papers would concentrate on specific national policies and practices. Another result of the workshop was a list of potential consultants from which the Principal Investigator would invite four specialists to participate in the research project.

### CONTRIBUTIONS TO BASIC SCIENCE

This effort will help to elucidate some of the fundamental challenges which must be met during the course of formulating the characteristics of theories of leadership during a period of change. One of the studies will focus on the difficulty of adapting traditional models of leadership to structural changes within the military organization and to shifts in patterns of civil-military relationships. Other consultants will consider such topics as leadership in relation to the cultural values of armed forces in contemporary Europe.

### POTENTIAL APPLICATIONS

Western military establishments in a period of détente encounter a number of uncertainties in their quest for the most appropriate contemporary leadership styles and strategies. The pace and scale of change in modern day armed forces is such that traditional situational leadership associated with well established means and objectives may no longer be sufficient. At a time when the nature of primary goals, long-term norms and societal preferences makes it difficult to identify and prioritize individual

organizational strategies, it is useful to review the overall experience of national military establishments.

# **International Military Education and Training: A Sociological Analysis**

Contract: DASW01-95-K-0003

Contract Dates: 6/1/98 – 6/30/01

Institution: Northwestern University

PI: Charles Moskos

## **SCIENTIFIC OBJECTIVES**

One objective of the research is to bridge methodological and theoretical issues found in general social science with those dealing with military organizations. We intend to advance the understanding of intercultural relations between and within large-scale organizations. One specific goal is to specify factors that help or hinder integrity among military personnel. As with prior ARI-sponsored projects, the research agenda is also subject to direction from senior personnel in the military and U.S. government. The research goals are explicitly dynamic in order to incorporate developments during the period of the research

## **APPROACH**

Since 1950, some 500,000 international military officers and senior enlisted personnel have received professional training through the International Military Education and Training (IMET) program of the United States. In the Post-Cold War era, IMET plays an even more important role with regard to fragile democracies, integrity standards of security officials, multinational operations, and a range of nontraditional missions (e.g. peace keeping, humanitarian, and nation building) as well as conventional military concerns.

The approach is threefold: (1) research on IMET participants in the United States, (2) research on IMET graduates in their home Countries, and (3) research on comparable programs in advanced Western democracies. The methodology will be primarily in-depth interviews with students, graduates, and staff members of professional military education programs.

## **PROGRESS**

The IMET study is in its early phase, but interviews have already been conducted with IMET graduates in Japan, Netherlands, and Israel. Cooperation with the directors of war and staff colleges in the United States has been excellent.

The major accomplishment at this time is the forthcoming publication (Fall, 1999) of The Postmodern Military: Armed Forces After the Cold War (Oxford University Press). The editors are Charles Moskos, John A. Williams, and David R. Segal. The volume contains chapters (written by local social scientists) on Australia, Denmark, Canada, France, Germany, Israel, Italy, Netherlands, South Africa, and the United Kingdom.

A second publication will be a new edition of Reporting War When There Is No War: The Military and the Media in Peacekeeping and Humanitarian Operations. The first edition was published in 1996 and distributed to every public affairs officer in the U.S. military as well as many senior officers and heads on non-government organizations. The reception accorded the first edition has created a demand for an updated volume. The key findings were given in reports pertaining to contract # DASW01-95-K-0001.

A third avenue of research is related to the enhancement of democratic civil-military relations. In this regard, the Principal Investigator serves as the academic advisor to Vice President Gore's International Conference on Upholding Integrity and Fighting Corruption Among Security and Judiciary Officials. Conference dates are: February 24-26, 1999. One of the PI's roles is to present an overview research agenda on de-corruption of armed forces.

#### CONTRIBUTUIONS TO BASIC SCIENCE

The data along with the concepts introduced in this research on comparative military organizations will inform social scientists doing basic research in several areas. One is the role of multicultural communications within formal organizations. A second is the nature of media relations in diverse societies. A third is to document the relative weight of cultural, organizational and economics variables in fostering or reducing levels of corruption in security officials. This latter research will be relevant to those who study law enforcement as well as military organizations. In addition, the research demonstrates the utility of a multi-method approach to sociological issues: survey data, focus groups, interviews, comparative organizational analysis, and participant observations. The Postmodern Military: Armed Forces After the Cold War will be the first comprehensive work in the military sociology in the post-Cold War era.

#### POTENTIAL APPLICATIONS

(1) Regarding the IMET study, one of the most significant concerns of the United States military is cooperation with the armed forces of other countries. That this study was initiated by the Joint Chiefs of Staff indicates the centrality of this issue for American national security. (2) Regarding the outcome of the Conference on Upholding Integrity and Fighting Corruption Among Security and Judiciary Officials, the applications are yet to be ascertained, but it is probable that the Vice President's Conference will issue a statement of recommendations and potential applications.

# Social And Cultural Dynamics Of American Military Organization

Contract #: DASW01-95-K-0005  
Institution: University of Maryland at  
College Park

Contract Dates: 6/30/95-5/30/00  
PI: David R. Segal & Mady Wechsler  
Segal

## SCIENTIFIC OBJECTIVES

The objectives of this research are (a) to increase our knowledge of the nature of the interface between the contemporary American military institution and the broader American society, in order to better understand the dynamics of how civilian institutions impact upon the military and vice-versa; (b) to explore specifically the interface between the American military and the American family as social institutions, in order to better understand how the family serves as a boundary-spanning institution between the civilian and military sectors of American society; (c) to increase our understanding of the behaviors, attitudes and values of contemporary American military personnel so that as the military becomes an increasingly diverse institution socio-demographically, human resource management can be increasingly rooted in scientific understanding of human behavior; and (d) to view the American military institution in the context of more general organizational changes in military institutions in other nations. This last objective will help us better understand which of the changes we observe in the American military are unique to our nation, and which are more general phenomena, common to the armed forces of western industrial nations. Two major themes that cross-cut these objectives are the increasing social diversity of our military force, and the range and number of peace operations in which our Army has been involved during the 1990s.

## APPROACH

This research involves both qualitative analysis and statistical modeling of quantitative data of American civilians (including those approaching military age-eligibility), civilian spouses of American military personnel, and American military personnel themselves. This research also involves deriving data from a variety of documentary sources on relationships between armed forces and society in other nations. Three research questions are posed with regard to each of the three populations mentioned, as well as with regard to the cross-national research.

The three primary questions addressed by the research on the American public are: what characteristics predict which young Americans will serve in the military; what are the consequences of having served in the military in terms of occupational status, education, and earnings after reentry to civilian life; and what is the nature of social support for the military missions of the 1990s among the American public?

The three primary questions addressed by our research on military families are: how do the family policies of an organization (in this case the Army) affect the commitment of family members to the organization; what are the effects of military culture and military operations on the families of military personnel; and how do military personnel who are forward deployed or forward stationed maintain contact with their families on the home front?



The three primary questions addressed by our research on military personnel are: what are the basic values of entry-level personnel, and are they compatible with the needs of the military of the future; what are the impacts on the attitudes and behaviors of American soldiers of the range of missions that they performed in the 1990s; and are these attitudes and behaviors compatible with the management of a socio-demographically diverse military force?

The three primary questions addressed by our cross-national research are: what are the social roots of military service in democratic states and how is military service changing as modern states increasingly move from conscription-based forces to volunteer forces; what have been the similarities and differences observed among nations dealing with increased socio-demographic diversity, and particularly with gender integration and sexual orientation integration; and how are other nations experiencing the processes of military down-sizing and base closing?

### PROGRESS

In each of these areas, some work has been completed, much is currently underway, and further work is planned. With regard to our research on the American public, analyses of data on the high school class of 1972, which provided most of the first volunteers for our post-conscription force, allowed us to model who served and who didn't, and among those who served, to model the characteristics that differentiated officers from enlisted personnel. In particular, this research highlighted the importance of propensity to serve as a predictor of service for the very first volunteer force cohort (72% of those who served stated such plans while still in high school), with greater impact of such plans for officers than for enlisted personnel. We have been collaborating with colleagues at the University of Michigan in analysis of data from high school seniors in the graduating classes of 1975-1997, studying patterns of enlistment propensity and actual enlistment behavior. We find that 70% of male high school seniors who report high propensity actually enlist within six years of high school graduation. Analysis of racial and ethnic differences in patterns of enlistment propensity demonstrate that the much noted decline in propensity in the early 1990s was due almost wholly to a decline in the propensity of African-Americans, who had been the highest propensity group during the first two decades of the volunteer force, and who moved closer to other groups in the 1990s. We also find that enlistment propensity among Hispanic high school seniors is higher than among white non-Hispanic seniors, and that the under-representation of Hispanics in the military is due to their rate of non-completion of high school, not their desire to serve. The results of this research are scheduled for publication in a series of professional journals. Research has been started exploring the conditions under which the American public supports the military missions of the 1990s, and papers have been presented at professional conferences. Further analyses are underway and publications are planned.

With regard to military families, David R. Segal, in collaboration with Morten G. Ender, has explored the ways in which soldiers and their families use non-traditional communications technologies to maintain contact between forward-deployed troops and their families at home. Mady Segal, in a series of research projects with Chris Bourg and David Rohall, have demonstrated the importance to commitment and morale of soldier



perceptions that the Army is supportive of families. The findings of this research are scheduled for publication in scientific journals.

With regard to soldier attitudes and behaviors, David and Mady Segal, in collaboration with John Hammill, have explored the values some of America's future Army leaders. David Segal, in collaboration with ARI's Ronald Tiggie, has explored the peacekeeping attitudes of reserve component soldiers who served in the Sinai MFO. David Segal, in collaboration with Brian Reed, has shown that in one of the Army's most frequently deployed divisions, operational tempo has a negative effect on morale, but not on reenlistment intention.

### CONTRIBUTIONS TO BASIC SCIENCE

The nature of the human life course has become a major paradigm in the social and behavioral sciences, and our work on both the antecedents and social consequences of military service has helped shape this paradigm. Much of our research in this area deals with the impact of service on veterans who return to the civilian labor force. Our work on military families reflects one of the major contemporary research areas in the sociology and psychology of the family: the work/family interface. Our work has used the Army as a test-bed for many of the theoretical principles in these fields. Likewise, organizational psychology and sociology, which for most of their histories have focused on organizational growth, have for the last decade changed their foci to organizational downsizing. Our work on increased operational tempo in a smaller Army has served as a major source of empirical data on what happens to an organization and its personnel when it becomes smaller while its missions seem to be expanding, and our work on the down-sizing of the Russian army makes a unique contribution to the dynamics of down-sizing in the former Soviet Union. In general, our comparative work has expanded the scope of the field of military sociology, which for most of this century has been primarily the sociological study of the American military. Our work provides a basis for exploring the generalizability of organizational concepts and relationships formerly explored primarily in the U.S. context.

### POTENTIAL APPLICATIONS

Three potential applications of our research have already become evident: the translation of results of research on military families into guidance on how to support families of deployed soldiers; the impact of our research on the relationship between enlistment propensity and actual enlistment behavior on the policy debate on recruitment strategies; and the attention paid by the policy community, including the Office of the Secretary of Defense, the Defense Science Board, and the General Accounting Office, to our findings on the dimensions and importance of the quality of life in the military. Other life-course research can contribute to the development of programs to ease the transition from military to civilian life. Our research on the use of modern communication technologies by deployed soldiers can help guide policy-makers both in maximizing the positive impacts of these technologies on soldier morale, and in considering the information security problems associated with the use of these technologies. Our research on the attitudes and behaviors of military personnel can help inform Army doctrine on what kinds of soldiers should be used in stability operations, and what kinds

of special training they may require. And our cross-national research allows us to identify human resource management strategies that have been implemented in other nations that might be useful here, or strategies that have been considered here but have already been shown in other contexts not to be effective.

## Summary of Research on Army Culture

Contract #:DASW01-98-M-1868  
Institution: University of Ottawa

Contract Dates:5/98 - 1/31/00  
PI Name: Donna Winslow

### SCIENTIFIC OBJECTIVES

The goal of this research is to produce an analysis of the literature pertaining to Army culture. It will assist in understanding the relationship between the Army's organizational culture (basic assumptions, spirit, beliefs, and the characteristic ways of doing things, that are shared by the members of the organization) in order to better interpret the role these elements play in the functioning of the Army.

### APPROACH

The analysis will examine the material available in three fields of study: anthropology, organizational studies and military sociology. The first step will be to produce an annotated bibliography of written documents pertinent to the theme of military culture. The goal of the annotated bibliography is to produce a summary and critique of each article and book selected. The basis for selection will be the document's relevance to the understanding of Army culture and in particular the three following aspects: 1) the definition of Army culture; 2) the observation of Army culture; and, 3) the change of Army culture. Drawing upon these documentary sources an analysis of the literature and its relevance to the understanding of Army culture will be produced. This analysis will then form the basis for developing a briefing package for commanders on "military culture".

### PROGRESS AND PLANS

We are currently in the process of preparing the annotated bibliography. We have been using keyword searches, "shelve searches" and "snowball" searches, that is, we explored review articles in addition to the bibliographies of the books and articles selected to find related literature. To date 6768+ matches have been found of which 2060 were relevant. Out of these 527 articles and books have been kept for the annotated bibliography. In the next phase of research we will complete the review of the relevant literature and write a paper on what can be understood about Army culture from the literature. Then a briefing package for Army commanders will be prepared drawing upon the extensive review of the literature. This package will consist of a computer based presentation package following the three axes outlined above: 1) the definition of culture; 2) the observation of culture; and 3) the change of culture. Each axe would be described as it pertains to issues pertinent to command of Army units. The briefing package will be field tested and modified according to the feedback received.

### CONTRIBUTION TO BASIC SCIENCE

The research will outline how to recognize and understand Army culture. It will draw conclusions on how culture can affect the functioning of an Army unit. It will also describe how individuals as well as internal and external forces can change the culture of an organization such as the Army.

### POTENTIAL APPLICATIONS

This analysis will also serve as the basis for developing a briefing package for Army commanders on military culture, how this culture can affect the functioning of their unit and how they, in turn can affect the culture of the units they command. What is relevant for an Army commander is the knowledge that culture is much more than leadership or a set of values. It can, however, be used to reinforce certain values. How does culture affect performance and discipline in a unit? What is the difference between culture and ethos? How can culture affect command climate and unit morale? It is also important to understand how to observe culture in order to determine what the actual unit culture is and in order to monitor changes. From the literature we believe that it will be possible to identify appropriate ways of "measuring" Army culture, that is, methods which can be used to observe behaviors and social structures within a unit. Finally it is important to understand how forces external and internal to an organization can change an organization's culture.

## ***Recently Completed Research***

## **Military Service in Adult Development and Health**

Contract #: MDA 903-93-K-0013

Institution: University of North

Carolina, Chapel Hill

Contract Dates: 7/1/93-10/31/98

PI(s): Glen H. Elder Elizabeth C. Clipp

### **SCIENTIFIC OBJECTIVES**

Building on nearly two decades of longitudinal studies of veterans, this multi-year study investigates the life-course and health effects of military service and wartime stresses, with emphasis on World War II. The data mainly come from the Stanford-Terman Study (Ss born 1903 through 1920), a project that recruited high-ability youth from large school systems in the state of California. Approximately 330 men participated in World War II and were born before 1925. Of this total, 236 are known to have served overseas and 204 were involved in combat. Only 64 men remained in the United States. Other data come from an Iowa panel study of parents and their children (nearly half of the fathers served in Vietnam) and from the life-history records of over 150 men in the Berkeley, California, longitudinal studies, birth years in the 20s.

The research objectives are organized around four sequenced tasks across the life course:

- (1) selection influences -- linking pre-service histories to military-wartime experiences;
- (2) the interaction effects of life history and military-wartime experiences on postwar adjustments;
- (3) life-span continuity and change -- the influence of military-wartime experiences on life patterns and health in the middle years; and
- (4) the later-life patterns of health and aging, post 1960s. The fourth year's objectives center mainly on the relation between war mobilization (homefront industrial work and military service) and the life course from 1948 through the 1960s.

The term "life course" refers to both socioeconomic (work, income) and health (emotional and physical) trajectories over the latter years of life.

### **APPROACH**

This study uses both life course theory and relevant designs/statistical models to address the above objectives (Elder, 1998) discussed at length in earlier reports. The theory assumes that pathways to military service and the enduring effects of military-wartime experience depend in large measure on the life stage at which men entered the military. The later the entry, the greater the life course disadvantage. In order to assess these effects, we used a comparative cohort design, men who were born before 1911 and after 1910. A related approach compares men who entered the service relatively early and late. Early entrants tend to come from the younger birth cohort.

In addition, we have investigated two pathways of manpower mobilization during the Second World War: military induction and employment in war industry.

Approximately 42 percent of the men served in the armed forces, and 25 percent were employed in war industries. Military service is characterized in terms of overseas duty, combat, theatre of service, and rank mobility. Selective service policies during the war favored young, single men, though occupational expertise became increasingly more important. Medical and legal expertise received priority for the armed forces, whereas engineering and scientific expertise was favored for war industries on the homefront.

Statistical models in our work have varied this year according to the problem at hand, from path analytic approaches to the dynamic models of event history analysis, logistic regression, and random as well as fixed models. For example, in order to assess the impact of wartime service on men's economic careers in late life, we used HLM to estimate influences on level of income and rate of economic change. Were men who entered the service late at a substantial handicap in earnings immediately after World War II? And did this disadvantage increase over time or did it remain unchanged?

### PROGRESS

Two sets of findings have emerged from our research: (1) the impact of war mobilization on men's worklife, and (2) on men's earnings.

Worklife effects. Despite the uncertain relation between selective service policies and their implementation, we find a strong correspondence between them. Regardless of age or cohort, men who were physicians, lawyers, or managers were selected into the military; the engineers and scientists were selected into war industry employment. The men who were not employed were not more likely to be students. Postwar work experience was indexed by occupational change, managerial role (up to 1948), and career continuity or discontinuity. Occupational disruption was common among both young and old. The younger cohort of men experienced more change than the older men, though we find a high degree of career continuity between the prewar years and postwar years in both birth cohorts. Military service tended to strengthen continuity, whereas homefront mobilization increased the amount of change by exposing men to job opportunities.

Income effects. Men who entered the service at an older age (after the age of 30) generally experienced a significant earnings disadvantage immediately after the war and this disadvantage increased over the first postwar decade. Despite their higher educational status, the late entrants differ most sharply in relation to the never-mobilized men (neither military nor war industry). Between these groups are men who entered the military at a relatively young age and those in home-front industry. These effects are best explained by mobilization effects on men's worklife immediately after the war, in pulling men out of productive careers, and in generating worklife discontinuity. By comparison, war mobilization did make a positive contribution to the earnings careers of men who entered the service at a younger age.

### CONTRIBUTIONS TO BASIC SCIENCE

The legacy of WW II is expressed through the aging experience and health of over half of all American men who have passed their 65th birthday. In this research program,



we have identified some of the key pathways by which this wartime experience made a difference in the lives of these men.

#### POTENTIAL APPLICATIONS

World War II provides a naturalistic data on the effects of differential age at entry into military service. The adverse effects of late entry in this research should provide information on the advantages and disadvantages of late mobilization, as during the Gulf War and use of the active reserves. A second application involves knowledge of the lifelong effects of military service and it's relevance for recruitment personnel.

# **Predicting Enlistment Propensity of Young African Americans**

Contract #: DASW01-95-K-0011  
Institution: University of the  
District of Columbia

Contract Dates: 8/11/95 - 8/11/98  
PI(s): Anne Hughes & Daryao Khati

## **SCIENTIFIC OBJECTIVES**

This research study was designed to develop and test a structural model to predict the inclination to enlist in the military (enlistment propensity) of young African American males and females, ages 16-19 years, who are enrolled in four public high schools in the District of Columbia. Specifically, this model was intended to investigate the potential relationships among four clusters of conceptual variables for predicting enlistment propensity as defined. The four clusters of variables have been designated as: (1) socioeconomic status (SES), (2) perceptions of latent goodwill (LGP) towards the military, (3) individual attributes (IA), and (4) simulated conditional choice (SCC) regarding future plans. As conceptualized, the model was to produce sets of interactive and recursive relationships with regard to predicting positive attitude toward enlistment (enlistment propensity) of young African Americans.

## **APPROACH**

The respondents were all selected from four different senior high schools to reflect lower, lower/middle, and middle socioeconomic status. The total sample of 460 respondents has been equally divided by gender and grade level.

A semi-structured interview schedule was specially designed in order to provide the data needed for the four clusters of variables. The instrument required no more than 12 minutes of direct face-to-face interviewing time. Writing down the responses to various items by the interviewers was held to a minimum through the use of checklists, key words and phrases, and simulation grids. All interviewers were trained by the research team.

The analysis of data used two different techniques: (1) a logistic regression model to determine the best set of predictor variables at three decision points and (2) summary statistics to provide descriptive findings.

## **PROGRESS**

The data set has been analyzed according to the response patterns of three groups of respondents at three decision points. The three groups are: (1) those who display unaided propensity to enlist and who's first choice is to join a service after completing high school (Decision Point I), (2) those who display an unaided propensity when first choice does not work out and second choice is an expressed inclination to join a service (Decision Point II), and finally (3) those who display aided propensity, when neither first nor second choice works out and information about the benefits of joining a service are explained, third choice is an inclination to join a service (Decision Point III).

The following activities have been completed in the third year: (1) a logistic regression analysis to determine predictor variables for a favorable attitude toward joining the military, (2) descriptive analysis using frequencies and percents, (3) tables showing

the predictor variables for each group by SES were prepared and presented in the final research report, (4) conclusions and recommendations were refined and supplemented based on the results of logistic regression model, and (5) a study of outliers has been undertaken.

Overall, our results show that the model can predict an inclination to enlist (enlistment propensity) ranging from 70 to 100% probability for individual schools depending upon the SES of the respondents as shown by school. However, for each of three dependent variables when the total group (all schools) for that variable was included in the analyses, the probable inclinations ranged from 90 to 100% based upon the predictor variables used

Some general conclusions based on the logistic regression analysis are:

1. The most important predictor is the education benefit after service. This predictor was consistently present across all three groups and across all SES levels. Other benefits associated with military service, such as travel and adventure, are important predictors, but their actual weights could not be clearly determined for all groups.
2. The presence of a "well functioning" ROTC makes a difference, as illustrated by its value as a predictor at Coolidge High School (CHS) for all three groups. However, at Anacostia High School (AHS), ROTC was not an important predictor variable.
3. Our idea of "latent good will" proved to be an important predictor for the low SES population in the first decision, and it was important for the low-middle SES at the second and third decision points.
4. The TV advertisements did not appear as a predictor variable for any SES group at any of the three decision points.

Specific recommendations include:

1. The most promising groups of young African Americans for enlisting in the military service are from the lower socioeconomic status (SES). The military should focus specific recruitment efforts on this pool of young peoples.
2. The military should make a concerted effort to expand the pool of potential recruiters to include relatives who have served in the military and who now are living in the community, and high school counselors and other relevant school personnel in the lower SES areas. In the case of counselors and other school personnel, they need to be trained in the comparative benefits of all viable options after high school graduation for graduating high school seniors, and all of the benefits that are waiting for the graduates as a result of enlistment in a military service. At the present time, the counselors, in particular, are focusing on college or some other post-secondary education option.
3. The military should expand its recruitment effort to include locations where students and recent high school graduates congregate: recreation centers, unemployment offices, public minority institutions with open enrollment policies and community colleges. These locations are

recommended because a large number of lower SES students can be found at them; and they congregate at these places for mutual support. Also, for these young people, the decision-making for the future is often indefinite because their plans are not realistically thought through. The high attrition rate (around 80%) of minority students in higher education institutions bear this out.

4. At least some of the advertising brochures should be rewritten to address the reality of this population. Written presentations and sentence structures designed for the middle class will not communicate the benefits from enlisting in a military service to a population that essentially secures its information in short sound bytes and by word of mouth. In addition, a new theme for the Army slogan should be considered that emphasizes economic and educational benefits in the short term and improving one's own life opportunities in the long term.
5. In all three-decision groups, women were almost equally represented, and there is little family support beyond the high school years. Based on our general knowledge of this population as well as the results of the present study, an in-depth study of women in this population should be carried out to investigate the possible approaches that the Army can use to attract these women to enlist.

#### CONTRIBUTIONS TO BASIC SCIENCE

Since the decline in African American enlistment propensity was reported, starting in the early 1990's, the possible reasons for this decline have caught the attention of the different military services. This study focused on the other side of the issue: the factors that can enhance the enlistment propensity of young African Americans. In our study, we have identified the key predictor variables that are present in a person's reported inclination to enlist in the military. Furthermore, the logistic regression model proved effective in a complex study having categorical or nominal dependent variables. In addition, the survey research design with its strategy of telescoping the time-frame in the probable decision-making process of young African Americans to join the military is a valid approach with this group. Also, in our original proposal, we stated that the young African American population is not monolithic; the results of the logistic regression model have provided empirical validity for this statement.

#### POTENTIAL APPLICATIONS

This study has at least three potential applications: (1) an instrument that is tailored specifically to young African Americans, (2) a logistic regression model that can be effectively used to produce predictor variables that enhance the inclination to enlist in the military; and (3) results that show a need for major changes to be made in advertisement and recruitment procedures for successfully recruiting young African Americans.

## **Research Methods & Concepts On The American Soldier: The Post-Cold War Military**

Contract #: DASW01-95-K-0001  
Institution: Northwestern University

Contract Dates: 1/1/95 – 8/30/98  
PI: Charles Moskos

### **SCIENTIFIC OBJECTIVES**

The research bridges methodological and theoretical issues found in general social science with those dealing with military organizations. The field of military sociology started with World War II and largely developed in the context of the Cold War. With the end of the Cold War in 1990, the dominant paradigms of military sociology need major revision.

The research provides current data and new theoretical concepts to enhance the Army's effectiveness in the post-Cold War era. At the same time, new avenues of basic research are required in military sociology to contribute to the common fund of knowledge in the social sciences. The research goals are explicitly dynamic in order to incorporate developments during the period of the research.

### **APPROACH**

The approach is threefold: (1) participant observations and in-depth interviews with soldiers in garrison and in field situations, (2) survey methods, and (3) relating findings in military sociology to broader concepts in the general social sciences. In addition, a comparative study of armed forces in the post-Cold War era will draw upon researchers from selected Western democracies. The resultant volume will be the first standard work in military sociology in the post-Cold War era.

The research is also responsive to requests from the Army senior leadership and ARI for basic research on sociological and/or social psychological factors affecting American soldiers. This includes especially field research on American soldiers being deployed to crisis areas. Contributions to basic research will be methodological as well as substantive. The methodology consists, variously, of surveys, in-depth interviews, focus groups, field observations, archival materials, and statistical data. To date, field research was conducted with American Army units in Haiti (October, 1995) and Bosnia (June 1996).

### **PROGRESS**

The major accomplishment of the research period was the publication of two significant works: All That We Can Be: Black Leadership and Racial Integration the Army Way (Basic Books, 1996), and Reporting War When There Is No War (Tribune McCormick Foundation, 1996). In progress is a volume entitled "Armed Forces After the Cold War" which contains contributions by leading scholars representing some dozen Western democracies.

The survey phase of the project (N=756) focused on attitudes toward humanitarian and peacekeeping operations. These data were based on field trips with "Operation Restore Democracy" (Haiti), and "Operation Joint Endeavor" (Bosnia). These data are



now in computer format and findings in tabular form have been presented at ARI In-Process Reviews and as Preliminary Reports.

A number of potentially valuable findings emerged. In the peacekeeping research, key findings included: (1) soldiers displayed a large degree of sophistication in distinguishing levels of neutrality in peace operations; (2) combat soldiers were adaptable to peacekeeping roles, (3) the most onerous workload occurred in logistics units, and (4) the ban on alcohol proved to be a practical policy.

In the race relations study, key findings included: (1) differential perception toward race relations by black and white soldiers do not preclude effective mission performance; (2) Army programs to enhance the academic levels of minority and other youth are extremely effective, and (3) affirmative action is successful when it is based on promotion from the qualified pool (as is the Army policy).

In the media study, key findings included: (1) contrary to conventional wisdom, soldiers have more favorable attitudes toward the media than do civilians; (2) the media are much more autonomous viz. the military than in times past, (3) the policy of "embedded media" (whereby journalists were placed in units for several weeks) has both functional and dysfunctional consequences.

### CONTRIBUTIONS TO BASIC SCIENCE

The quantitative and qualitative data along with the concepts introduced in this research on American soldiers will inform other social scientists doing basic research in race relations, media relations, and organizational change. The ARI-sponsored research on race relations completed is already being cited in the relevant literature. In addition, the research demonstrates the utility of a multi-method approach to sociological issues: survey data, focus groups, interviews, comparative organizational analysis, and participant observations.

### POTENTIAL APPLICATIONS

The findings of the surveys and observations were reported directly to the Chairman of the Joint Chiefs of Staff, the Chief of Staff of the Army, the Deputy Chief of Staff for Personnel, and other senior Army officers. The President of the United States invited the principal investigator to the White House to give a presentation on race relations in the Army in conjunction with his review of affirmative action policies. Reporting War When There Is No War has been distributed to every public affairs officer in the United States military as well as many flag officers. In addition, the volume is standard reading at the war college level in all services.

#### **RACO RESEARCH OBJECTIVE #4:**

***Provide an understanding of individual characteristics  
that can serve as the basis for improving  
the match between soldiers and their jobs.***

Research in this section provides fundamental knowledge to guide the restructuring of the Army's occupational analysis program and job structure.



## ***Ongoing Research***

## **Occupational Analysis**

Contract #: DASW01-96-C-0051  
Institution: National Academy of  
Science/National Research Counsel

Contract Dates: 07/01/96 - 6/30/99  
PI: Anne Mavor

### **SCIENTIFIC OBJECTIVES**

The committee is performing the following tasks:

1. Reviewing and analyzing the research on occupations and careers that contribute to an understanding of the nature and structure of work;
2. Exploring the issues that influence the analysis and design of occupations;
3. Evaluating the dramatic changes in the computational tools for analyzing the nature of the work environment, including the rapid technological improvement in computer assisted surveys, data warehousing of occupational models and databases, and other relevant changes; and
4. Assessing the applications of methods and tools developed in the civilian sector to occupational analysis and classification in the Army.

### **APPROACH**

The committee organized itself into four working groups:

1. Occupational classification technology;
2. Databases on experiences at work;
3. New forms of work, and
4. Conceptualizing work from different perspectives.

The groups have developed agendas including commissioning papers, making site visits, and arranging briefings from experts on technical issues and databases.

### **PROGRESS**

The committee is in the process of completing a final draft of the manuscript. It is anticipated that the report will enter the review cycle shortly. The draft manuscript contains seven chapters. They include: (1) Introduction; (2) External Contexts of Work: Markets, Technology, and Workforce Demographics; (3) Changes in the Organizational Context of Work; (4) Changes in the Structure and Content of Work; (5) Implications for Occupational Analysis Systems; (6) Army Work and Approaches to Occupational Analysis; and (7) Conclusions and Implications. It is currently anticipated that the book will be published by the National Academy Press by the end of June, 1999.

### **POTENTIAL APPLICATIONS**

The results of this study will be useful to Army planners, researchers, human resources personnel (job designers, trainers, and employment counselors), and developers and users of occupational databases. It will document the state-of-the-art in occupational analysis (including possible cross-walks among different systems), suggest new ways of conceptualizing occupations in a rapidly changing economic and political climate, and provide a basis for developing new military occupational systems drawing on progress

made to date in the civilian sector. For the research community, the project will provide a framework to guide future analyses of the workplace. In addition, the study should also aid decision makers, such as senior executives, line managers, and Army officers, in better understanding the dynamics of the workplace and their ability to influence change.

## **Testing Schneider's ASA Theory**

Contract #: DASW01-96-K-0003  
Institution: University of Maryland at  
College Park

Contract Dates: 4/30/96-9/30/99  
PI: Benjamin Schneider

### **SCIENTIFIC OBJECTIVES**

The purpose of this contract is to test the hypothesis of homogeneity of personality of leaders, statistical modeling of this homogeneity, the relationships between leader personality and individual and organizational outcomes, and the role of the individual leader's personality in the behavior of the organization as predicted by Schneider's theory on attraction, selection, and attrition (ASA) of leaders in organizations. ASA theory proposes that, over time, specific leader personalities come to define organizational settings as an outcome of the ASA process.

### **APPROACH**

The scientific approach to work on the project has involved extensive data collection on leader personality and also leader life history experiences and the use of those data for predicting the organizations in which the leaders work. In addition, some research has also been conducted on adolescent leaders to begin to explore the early development and predictability of future adult leaders. Finally, considerable conceptual progress has been made in identifying additional issues in understanding the impact of leader personality on organizations.

### **PROGRESS**

Since the contract began there have been several published studies by Schneider and others that lend support to his fundamental hypothesis that homogeneity of personality of leaders in organizations is to be expected. Two studies of homogeneity have been carried out under the contract. The first studied a sample of 12,000 leaders from 142 American business organizations. These leaders had attended leadership training at the Center for Creative Leadership (CCL) in Greensboro, NC; each had completed the Myers-Briggs Type Indicator (MBTI). Schneider showed that a statistical model he developed based on the MBTI data could be used to significantly predict (a) the industry in which the leader worked and (b) the company for which the leader worked. In the second study, he showed that the life history experiences of attorneys and accountants could be used to develop a statistical model for assigning (a) accountants to one of the four accounting firms for which the accountants worked and (b) attorneys to one of two law organizations for which they worked.

Simultaneous with this work on leaders already in business, Schneider became interested in leadership among adolescents and the long-term predictability of (a) leadership for these adolescents and (b) the predictability of the kinds of settings in which they might eventually choose to work. He has shown that both adolescent personality and adolescent career orientations and interests predict teacher and peer ratings of leadership over time (18 months to date) and that these predictions differ from predictions of adolescent peer ratings of popularity and friendship.

These projects have resulted in a number of conceptual papers on the ways by which leader personalities and interests come to define organizations and the behavior of those organizations. Two themes have emerged in this conceptual work. One theme concerns the role of the individual leader's personality in the behavior of the organization; this stands in contrast to most writings on organizational behavior that attribute such behavior to structure and strategy. A second theme concerns explicit specification of the cross-level issues involved in exploring relationships between leader personality and individual and organizational outcomes.

#### CONTRIBUTION TO BASIC SCIENCE

With the exception of personnel selection researchers, organizational science has been dominated by a situationist perspective. This perspective implicitly and, in many cases, explicitly argues that organizations are what they are as a function of the jobs in the organization, the structure of the organization, the predominance of teams in the organization, the technology that characterizes the organization, and so forth. ASA theory takes a different tack, proposing that organizations are what they are due to the people in them. To test this idea, it must first be shown that organizations tend towards homogeneity and the two studies we have conducted to date lend some support to this hypothesis. From a fundamental science standpoint, these findings offer alternative explanations for organizational behavior. That is, the findings indicate that it may be that, at root, organizations take form as a function of the people in them rather than the more tangible or surface issues on which organizational scientists have previously focused.

#### POTENTIAL APPLICATIONS

The results to date suggest several potential applications, one regarding personnel selection and the other with regard to organizational change efforts. When harmony, cooperation, and morale are key outcomes of interest, ASA theory suggests that people who are similar to those already in the organization should be hired. This conclusion suggests the inclusion of issues related to hiring for the organization, not just the job, in personnel selection. ASA theory also suggests that, when organizational change is required, simple realignment or restructuring may not achieve the intended goals because the same people will still be in the organization; if people are the root of what an organization is then it is the people who require changing, not the structure of the organization.

Finally, the research on adolescent leadership may have important implications for the Army because of its focus on young adults and because of the focus on peer ratings of leadership. The finding that leadership is predictable may be of value in creating instruments to aid in the selection of soldiers for appropriate leadership assignments. These leadership selection instruments may also be used to help determine which soldiers are most likely to benefit from further leadership training.

## **Individual Differences in Environmental Spatial Cognition**

Contract #: DASW01-95-K-0014  
Institution: University of California,  
Santa Barbara

Contract Dates: 9/95-8/01  
PI(s): Mary Hegarty & Daniel Montello

### **SCIENTIFIC OBJECTIVES**

The scientific objectives of this project are: (1) to identify dimensions of environmental spatial abilities and to develop valid and reliable measures of these abilities, (2) to investigate how environmental spatial abilities (i.e., spatial and navigational ability in the real-world) are related to more traditional psychometric measures of cognitive abilities and to people's self reports of their own abilities, and (3) to study how environmental spatial abilities differ as a function of scale of space, whether people are navigating in real or simulated space, the amount of dynamic processing of space involved in a task, and the complexity of the space.

### **APPROACH**

We use a combination of correlational and experimental methodologies. In a large correlational study, we collected data from over 220 participants on several measures of environmental and more traditional spatial abilities. We will analyze these data to reveal the factor structure of environmental spatial ability and how environmental spatial abilities are related to other psychometric and self report measures. We have also conducted smaller correlational studies investigating static and dynamic spatial abilities at different scales and abilities related to production of verbal navigation instructions.

In addition, we are conducting a number of experimental studies that measure the effects of different factors on spatial performance. In one experimental study, we compared spatial learning from real and virtual environments and from maps. In another study we have compared the accuracy of different methodologies for collecting pointing estimates. In a third experiment we investigated how blindfold pointing is affected by path complexity. We are currently conducting experiments on the effects of image size (proximal and distal) on spatial learning and a study of learning from maps by scanning them sequentially.

### **PROGRESS**

We tested over 220 participants in our major correlational study of spatial learning in real and simulated environments, a blindfold pointing task, self-report measure of spatial ability, traditional psychometric measures of spatial, verbal and reasoning ability and measures of spatial and verbal working memory capacity. We are about to complete the coding of these data and we will now analyze them to reveal the factor structure of environmental spatial ability and how environmental spatial abilities are related to other psychometric and self report measures.

The development of the Santa Barbara Sense of Direction Scale, a 15-item self-report measure of environmental spatial ability is complete. This scale has an internal reliability of .88 and a test-retest reliability of .91. This scale is being administered in all of our experimental and correlational studies and is proving to be quite predictive of

performance in a range of environmental spatial tasks. We are preparing a manuscript for publication based on these results.

We completed a study of learning the layout of a building from a map, from direct experience, or by traversing through a "desktop" virtual rendition of the building. Participants in the virtual environment had the poorest performance, but their poor performance was limited to conditions in which they had to integrate information across different floors of the building. As expected, map learners formed an orientation-specific representation of the environment. Virtual environment learners also showed a preferred orientation, defined by their initial orientation in the environment. Learning a separate virtual environment was highly predictive of learning a real environment, suggesting that similar cognitive mechanisms are involved in the two learning situations. A manuscript reporting this research has been accepted for publication in *Memory & Cognition*. A follow-up study of spatial learning in virtual environments partially replicated the results of this study, and also investigated learning of spatial layout with more exposure to the environment. A report of this study was submitted to the journal *Presence*.

In another series of experiments, we compared methodologies for collecting pointing estimates of direction (azimuth). Two variables were manipulated: Pointing was either with a manual pointer or by rotating the body to face a particular direction (a digital compass worn around the waist provided the direction scores in the latter case), and pointing was done either completely blindfolded or while wearing a vision-restricting hood that allowed subjects to see the pointer and floor by their feet. Results indicate that pointing with a manual pointer lead to greater constant error (bias) in the data, whereas pointing by rotating the body lead to greater variable error. These and other results of this study are written up in a manuscript that has been resubmitted to *Perception*.

We have conducted two studies of individual differences in verbal navigation instructions. These studies showed that the quality of verbal navigation instructions could be assessed reliably by asking people to judge their quality. An extensive analysis of the instructions generated indicated that higher quality instructions are more complete, i.e. they mention more segments, turns and landmarks on the route to be described. An initial report of these studies has been submitted for publication in the proceedings of the COSIT conference, to take place in Hamburg later this year. A third study, almost completed, investigated whether route directions rated as better are in fact more effective, in that people who follow them are more likely to get to their goal.

We also have conducted an initial experiment on ability to learn paths of different complexity while blindfolded, and a study of static and dynamic spatial abilities at different scales. These experiments informed the design of our major correlational study and will be followed up in future research. We have also begun data collection for studies of the effects of image size (proximal and distal) on spatial learning and a study of learning from maps by scanning them sequentially.

## CONTRIBUTIONS TO BASIC SCIENCE

The project will increase our understanding of individual differences in environmental spatial abilities and their relation to other cognitive abilities. It will contribute to a broad theory of the psychology of space, distinguishing between spatial cognition at different



scales of space, different levels of spatial complexity, and in different environments (both real and simulated).

#### POTENTIAL APPLICATIONS

This research has practical application in such contexts as personnel selection, education and training. For example our results to date suggest that both navigation in a desktop virtual environment and self-report sense of direction are highly predictive of navigation in real environments, suggesting that these might be good measures to use in personnel selection. By investigating navigation in both real and simulated environments, our research will also provide important information related to the use of simulated environments in personnel training.

## ***Recently Completed Research***

## **Do Individual Differences in Motoric and Rhythmic Skills Intercorrelate?**

Contract #: DASW01-96-K-0005  
Institution: S. Carolina State University

Contract Dates: 8/19/96-6/15/98  
PI: Geoffrey L. Collier

### **SCIENTIFIC OBJECTIVES**

The role of rhythmic behavior occupies an increasingly central role in the study of motor skills. If rhythm does indeed play a central role in motor control, then it would be reasonable to extend this into the study of individual differences and hypothesize that people who have superior rhythmic abilities also have superior motor skills in general.

### **APPROACH**

In order to test this hypothesis, an exhaustive battery of motor skill tests and rhythmic abilities was performed on 46 subjects. Rhythmic ability was assessed by having subjects tap an isochronous (evenly spaced) beat to a metronome on a drum pad (for the hands) or drum pedal (for the feet), interfaced with a computer. After a certain number of taps, the metronome was discontinued and the subjects continued tapping without it. They did this separately for all four limbs at a variety of tempi, for several replications. A robust statistical measure of average variability across all replications was used as the index of rhythmic accuracy. Additionally, each subject was administered a test of bilateral auditory temporal acuity. Motor skills were assessed using a copious set of tests of motor skills, including tests of fine and gross motor skills, balancing, hand steadiness, speed and agility. Each of these was replicated twice. Additionally, background information on handedness, musical background, athletic background, and anthropometrics were taken.

### **PROGRESS**

Currently, preliminary analyses for 42 of the subjects for the motor batteries and 14 for the rhythm tests have been completed. The preliminary analyses of these subjects reveal a number of important results. First, individual differences in rhythmic abilities are modest. The ability to keep a beat is apparently a human universal. However, despite the restricted variance in rhythmic abilities, there are strong intercorrelations among all four limbs. That is to say, people who are accurate with one limb tended to be accurate with the other three. Furthermore, there are weaker positive correlations between rhythmic production and the test of auditory temporal acuity. In sum, despite the ability of all subjects to keep a fairly good beat, there are individual differences in temporal accuracy, with some evidence of cross-modal consistency.

We turn lastly to the key question of the relationship between rhythmic and motor skills. The cross-correlations between the rhythmic tests and the motor tests are almost entirely positive. The general pattern is that rhythmic ability, regardless of whether assessed with the hands or feet, appears to most strongly predict motor abilities involving the hands and finer motor skills, but is a weaker predictor of gross motor skills primarily involving the hands and feet. A tight coupling of rhythm tasks, regardless of limb, is seen throughout, indicating that rhythmic abilities among the limbs intercorrelated highly, even

between the hands and feet, and across the left and right sides. There are also positive (but nonsignificant) correlations between production and auditory temporal accuracy. Taken together, these results imply that a common mechanism or set of mechanisms centrally regulates temporal control, and that tests of temporal accuracy reflect mechanisms that play a role in motor control in general.

### CONTRIBUTIONS TO BASIC SCIENCE

This confirms the initial hypothesis. Rhythmic accuracy correlates positively with almost all of the motor tasks, and loads highly on the first, "general" factor of an unrotated principal components analysis. Further analyses of these data will hopefully clarify and strengthen these conclusions. In addition, a large body of simultaneous multilimb rhythmic performance data was acquired. These will enable us to study individual differences, not merely in timing control, but in timing control among the limbs. Temporal intercoordination is the essence motoric coordination. Thus, these analyses might reveal individual differences in coordination abilities not seen in single limb studies.

### POTENTIAL APPLICATIONS

This project focuses on the use of rhythmic ability to screen for motoric abilities. Rhythmic ability seems to be highly related to fine motor control, steadiness, and balance. These correlations were sufficiently strong that their practical use in tests designed to predict skill in pertinent occupations (e.g. electronics technician) deserves consideration. Thus tests of rhythmic ability could be developed that could increase the Army's power to appropriately select of soldiers for roles which require varying levels of motoric abilities.

# Personality, Motivation, and Cognitive Performance

Contract #: MDA903-93-K-0008  
Contract Dates: 7/12/93 - 9/30/97

Institution: Northwestern University  
PI(s): William Revelle & Kristen Joan  
Anderson

## SCIENTIFIC OBJECTIVES

This project examined the determinants of efficient cognitive performance. Specific questions addressed how environmental stressors combine with time of day and individual differences in personality to affect motivational variables that in turn affect components of information processing.

Specific objectives were: 1) to do systematic taxonomic work on the relationship between personality traits, situational moderators, and activation states; 2) to develop and test models of stable individual differences and transient affective states as they affect the detection, encoding, storage, and processing of information; and 3) to test and revise our models of motivational effects upon complex cognitive performance.

## APPROACH

We have used a parallel approach, conducting studies emphasizing natural variation in activation across time of day, experimental manipulations of activation using caffeine, film clips, and monetary incentive, and using a variety of cognitive tasks known to differ in their attention and memory demands. Given the complexity of the predicted pattern of results, we have stressed the replicability of our experimental findings, making sure that they generalize across multiple manipulations of activation state and multiple measures of cognitive performance.

## PROGRESS

Results showed that individual differences in temperament combine with a variety of stressors (e.g., time of day, exercise, stimulant drugs, feedback) to affect two components of motivational intensity, energetic arousal (tired vs. energized) and tense (calm vs. tense) arousal, and one of motivational direction. The two components of arousal have systematic effects on performance on a variety of simple and complex cognitive tasks. Cognitive performance measures examined included complex problem solving as well as attention, learning, memory and performance tasks. New techniques were developed that demonstrated the importance of within subject variation in energetic and tense arousal.

Measurement of activation. Combining within- and between-subject data from this and prior years allowed us to develop and test various ways of measuring individual differences in activation states. Analyses of an extremely large between-subject data set aggregated from studies conducted throughout the project allowed us to apply a number of psychometric techniques (e.g., factor analyses, item response theory procedures) to determine the dimensionality of activation states and to construct brief scales to assess these states during the waking day. These between-subject analyses showed that impulsivity interacts with neuroticism to affect the amplitude of both energetic and tense

arousal. Within-subject analyses demonstrated reliable individual differences in several parameters of these arousal rhythms (phase, amplitude, and coherence). These parameters are stable over several weeks and show consistent patterns of relationships with impulsivity and neuroticism.

Activation states and sustained attention. Our prior work examined the effects of time of day, personality, and motivation on sustained performance on a simple reaction time task. Arousal facilitated performance within this paradigm. Results suggested that (a) mean reaction times are negatively correlated with levels of self-reported energetic arousal (which in turn varies with time-of-day and which may be manipulated with caffeine). (b) Although increases in arousal minimize the extent to which sustained performance deteriorates over time, effort does not prevent that decline. (c) Impulsivity interacts with time-of-day such that the performance of high impulsives decays more in the morning than that of low impulsives, and this result reverses in the evening. Data from choice reaction time tasks have allowed us to reject several alternative explanations for our pattern of findings.

Combining these prior findings with our within-subject measures of arousal has allowed us to examine how phase differences in the diurnal arousal rhythm (measured within subjects over a week) predict individual differences in attentional performance. Simple and choice reaction time measures taken at different times of the day were reliably predicted by current levels of energetic arousal as well as the phase of energetic arousal estimated over the week.

Activation states and verbal working memory capacity. After disproving our original hypothesis that increases in arousal would be detrimental to working-memory capacity, a series of experiments indicated that verbal working memory capacity (i.e., the capacity associated with the executive function and articulatory loop) is a positively asymptotic function of energetic arousal. Six studies examined the impact of energetic arousal on working memory. Time of day, caffeine, and film clips were used to assure variation in energetic arousal, which ranges from feeling sleepy and tired to feeling lively and energetic. Both between-subjects and within-subjects data from two different working memory tasks (verbal and computational) indicated that higher levels of energetic arousal were associated with better working memory performance. This beneficial effect of heightened energetic arousal did not seem to be due to changes in attention, task strategy, or effort. Instead, the effect of enhanced effort was more consistent with changes in resource allocation than changes in resource availability. In contrast, higher levels of tense arousal were occasionally, but not invariably, associated with poorer working memory performance.

Activation states and visual working memory capacity. A series of three experiments address the impact of activation states on visual working memory capacity (i.e., the capacity associated with the executive function and visual-spatial scratchpad). Given patterns of lateralization for both visual processing and negative affect, one possibility explored by these studies is that tense arousal has a more consistently detrimental effect on visual working memory than verbal working memory. In contrast, it has been argued



that the primary impact of anxiety (which is akin to tense arousal) on working memory is because worry "occupies" the articulatory loop, suggesting that tense arousal should have minimal impact on visual working memory (which does not rely on the articulatory loop). Two between-subjects studies indicated that tense arousal was associated with reduced sensitivity to stimuli encountered in a visual working memory task. The effects of energetic arousal were less consistent, with some suggestion that energetic arousal may have a limited beneficial effect. A third within-subjects study was then conducted. Participants completed the visual working memory task both before and after being shown one of four film clips selected to independently manipulate energetic and tense arousal. The data collection phase of this study recently ended; data analyses has not yet been conducted.

Activation states and long-term memory. Two studies of the impact of energetic and tense arousal on long-term memory were completed earlier. Although the results of the two studies were not fully convergent, they suggest that the combination of low energy and high tension and time of learning may be particularly detrimental to long-term recall. Data from a follow-up to one of those studies were recently analyzed, and indicated that energetic arousal at time of learning had a statistically reliable beneficial effect on long-term memory scores as much as a year after the initial learning context.

### CONTRIBUTIONS TO BASIC SCIENCE

This project has concerned itself with the individual, diurnal, and situational determinants of efficient cognitive performance. Our results show that activation states are a systematic function of stable dimensions of individual differences, circadian rhythms, and many common stressors. These activation states in turn have systematic effects on cognitive performance. By combining information about an individual's stable personality traits and transient motivational states with a consideration of the situational and task demands, it is possible to more accurately predict both simple and complicated cognitive performance than when individual differences and motivational states are not taken into account. Our results also show the benefit of combining traditional individual differences psychology with motivational and cognitive approaches, in that the consistent patterns of results we have obtained tend to reflect the interactions of traits, situational stressors, and task components.

### POTENTIAL APPLICATIONS

Prior work has shown that small variations in performance on elementary cognitive tasks are associated with larger variations in performance on higher level tasks. Activation states vary systematically across the day and as a function of task demands and situational stressors. Cognitive tasks with different demands on attention and working memory show different patterns of results as a function of activation state. Rapid online measurement of these states as well as the prediction of future states as a function of diurnal variation and stress is now possible and allows for predicting performance increments and decrements. These predictions could be of high utility for the Army for using individual differences in arousal patterns for selection, design of training programs, and scheduling task assignments.